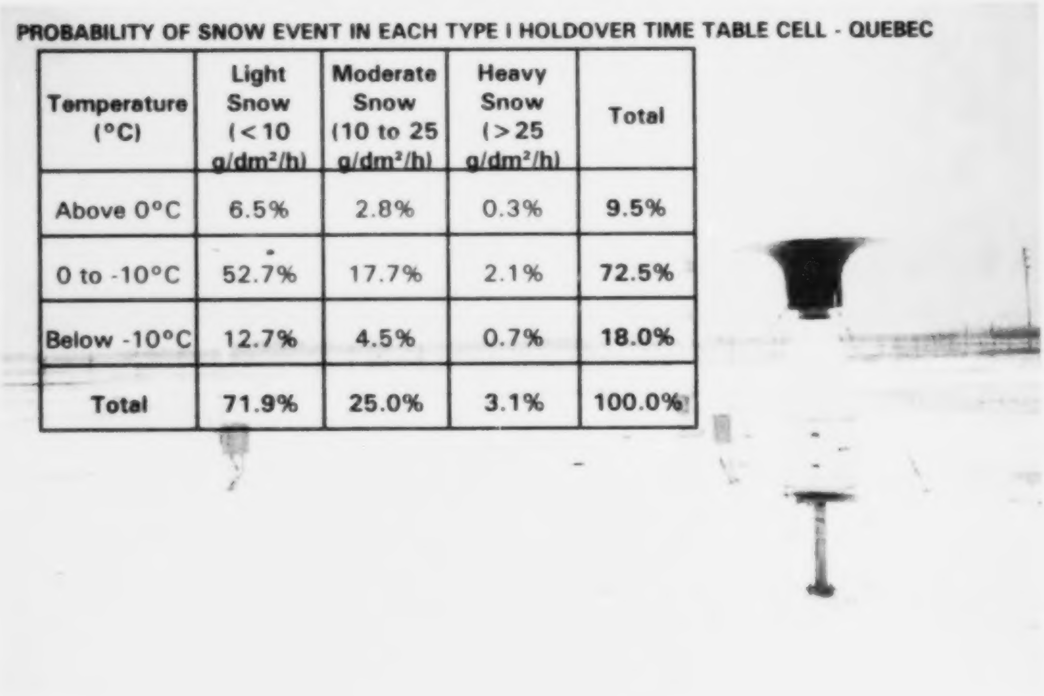
# Winter Weather Data Evaluation
# (1995-2001)



**PROBABILITY OF SNOW EVENT IN EACH TYPE I HOLDOVER TIME TABLE CELL - QUEBEC**

| Temperature (°C) | Light Snow (< 10 g/dm$^2$/h) | Moderate Snow (10 to 25 g/dm$^2$/h) | Heavy Snow (> 25 g/dm$^2$/h) | Total |
|---|---|---|---|---|
| Above 0°C | 6.5% | 2.8% | 0.3% | **9.5%** |
| 0 to -10°C | 52.7% | 17.7% | 2.1% | **72.5%** |
| Below -10°C | 12.7% | 4.5% | 0.7% | **18.0%** |
| **Total** | **71.9%** | **25.0%** | **3.1%** | **100.0%** |

Prepared for

**Transportation Development Centre**
On behalf of
**Civil Aviation**

**Transport Canada**

APS AVIATION INC.

October 2001

Final Version 1.0

106-00570/

TP 13830E

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# (1995-2001)

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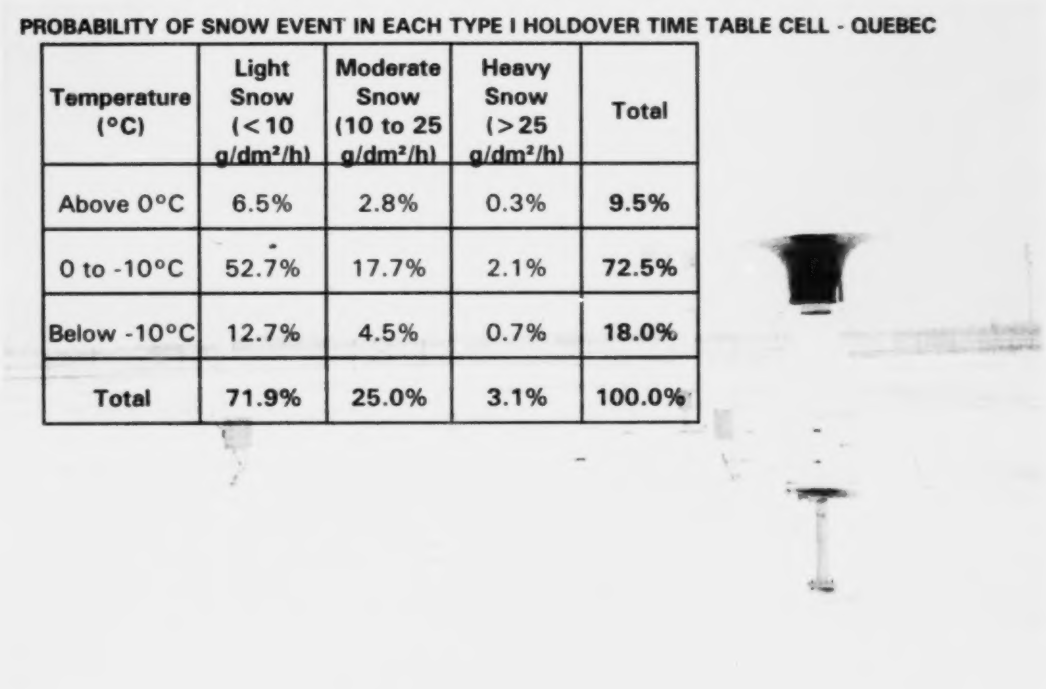

by

Nicoara Moc

APS AVIATION INC.

October 2001

Final Version 1.0

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

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Un sommaire français se trouve avant la table des matières.

# PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To conduct endurance time frost tests for each temperature to substantiate the values in the current SAE holdover time guidelines for Type IV, Type III and Type I fluids;
- To evaluate weather data from previous winters to establish a range of snow precipitation suitable for the evaluation of holdover time limits;
- To develop a protocol for Type I fluid testing;
- To examine the change in viscosity during the application of Type IV fluids;
- To compare holdover times in natural snow with those in NCAR's artificial snow;
- To prepare the JetStar and Canadair RJ wing for thermodynamic tests;
- To further evaluate the flow of contaminated fluid from the wing of a Falcon 20D aircraft during simulated take-off runs;
- To further evaluate hot water deicing;
- To provide support for tactile tests at Toronto Central Deicing Facility; and
- To investigate the use of ice sensors in the pre-take-off contamination check.

The research activities during the winter of 2000-2001 are documented in six reports. The last four objectives listed above have not yet been finalized and are not included in this series of reports. Results will be reported upon study completion. The titles of the documented reports are as follows:

- TP 13826E Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000-01 Winter;
- TP 13827E SAE Type I Fluid Endurance Time Test Protocol;
- TP 13828E Endurance Time Testing in Snow: Reconciliation of Indoor and Outdoor Data;
- TP 13829E Modification of Test Wing to Accommodate Fuel Load Effects for Deicing Research: 2001;
- TP 13830E Winter Weather Data Evaluation (1995-2001); and
- TP 13831E Endurance Time Tests in Simulated Frost Conditions: 2001.

In addition, an interim report entitled *Viscosity Measurement of Type IV Fluids on Wing Surfaces* will be written.

This report, TP 13830E, documents the project with the following objective:

- To evaluate snow weather data from the 2000-01 winter and several recent winters to establish a range of snow precipitation rates suitable for the evaluation of holdover time limits.

This objective was met by acquiring and analyzing winter weather data recorded by automated weather instruments at meteorological stations from six sites in Quebec, Canada. The data collected during the winters from 1995 to 2001 were statistically analyzed to determine the cumulative probabilities of high precipitation rates in specific air temperature intervals.

## ACKNOWLEDGEMENTS

This research has been funded by the Civil Aviation Group, Transport Canada, with support from the U.S. Federal Aviation Administration. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, American Eagle Airlines Inc., the National Center for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Hudson General Aviation Services Inc., Union Carbide, Cryotech, and Fortier Transfert Ltée for provision of personnel and facilities and for their co-operation with the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data.

Special thanks are extended to Frank Eyre and Barry Myers of the Transportation Development Centre for their participation, contribution, and guidance in the preparation of this document.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Six reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

Precipitation rate/temperature data from previous winters were studied to ascertain the suitability of the precipitation rate ranges used for holdover time evaluation. This report is a follow-up to the snow weather data report published in 2000 and encompasses all the data from that report. This study was performed to expand the available data set.

Data were acquired from Environment Canada from six automated weather stations in the province of Quebec, Canada, located in Dorval (Montreal), Quebec City, Rouyn, Pointe-au-Père, Frelighsburg, and High Falls. A total of 3000 hours of snowstorm data recorded between 1995 and 2001, and over 235 hours of freezing rain data were analyzed. Included in the data set were over 950 hours of snow data from the 2000-01 winter.

Data relating to the frequency of frost occurrences, and freezing fog and frost deposition rates measured during natural conditions are included in this report.

For the 2000-01 winter, precipitation rates above 25 g/dm²/h were not found in the holdover time temperature range of -14 to -25°C. The 70th percentile for precipitation rates was observed to be approximately 10 g/dm²/h and only 4 percent of the precipitation rates were above 22 g/dm²/h for the total snow weather data.

Based on the storm data, it was observed that the precipitation rate limits of 10 and 25 g/dm²/h used to establish the holdover times are satisfactory. However, the holdover time tables can be simplified by reclassifying the temperature ranges and improved by adding the intensity of precipitation (light, moderate, heavy) for snow. Efforts should be made to reformat the holdover time tables.

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Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à six rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

Les données concernant les taux de précipitation/températures colligées au cours des derniers hivers ont été étudiées afin de confirmer la pertinence des intensités de précipitations utilisées pour évaluer les durées d'efficacité des liquides antigivre. Le présent rapport s'inscrit dans la suite du rapport sur les données concernant les précipitations neigeuses publié en 2000, et il englobe toutes les données de ce rapport. La présente étude avait pour but d'enrichir l'ensemble de données déjà constitué.

Les données, obtenues auprès d'Environnement Canada, provenaient de six stations météorologiques automatisées situées au Québec, Canada, soit à Dorval (Montréal), à Québec, à Rouyn, à Pointe-au-Père, à Frelighsburg et à High Falls. Un total de 3 000 heures de données de précipitations neigeuses, enregistrées entre 1995 et 2001, et plus de 235 heures de données de pluie verglaçante, ont été analysées. Sont comprises dans l'ensemble de données plus de 950 heures de données de précipitations neigeuses recueillies au cours de l'hiver 2000-2001.

Ce rapport comporte également des données sur l'incidence des gelées et sur les taux de dépôt de brouillard verglaçant et de givre, mesurés en conditions naturelles.

Pendant l'hiver 2000-2001, aucun taux de précipitation supérieur à 25 g/dm²/h n'a été enregistré, à des températures comprises entre -14 et -25 °C (une des plages de températures des tableaux des durées d'efficacité). Le taux de précipitation correspondant au 70$^e$ centile était d'environ 10 g/dm²/h et seulement 4 p. 100 des taux de précipitation dépassaient 22 g/dm²/h, pour l'ensemble des données sur la neige.

D'après les données sur les précipitations neigeuses, les valeurs limites des taux de précipitation (10 et 25 g/dm²/h) utilisées pour établir les durées d'efficacité s'avèrent satisfaisantes. Toutefois, on pourrait simplifier les tableaux des durées d'efficacité en revoyant les plages de températures, et les améliorer en ajoutant une colonne pour l'intensité des précipitations neigeuses (légère, modérée, abondante). Bref, il y aurait lieu de revoir la présentation des tableaux des durées d'efficacité.

17. Mots clés
Neige naturelle, taux de précipitation, données météorologiques

18. Diffusion
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# EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a research program to further advance aircraft ground de/anti-icing technology. As a part of this program, APS undertook a study to evaluate precipitation data (precipitation rate/temperature data) from several winters to confirm the suitability of precipitation rate ranges used for holdover time evaluation.

In addition, information collected from other research that relates to winter weather data has been compiled and is included in this report.

The information contained in this report can be used to evaluate potential refinements to the SAE holdover time table format.

## Description and Processing of Data

A total of 2 998 hours of storm data points was compiled from precipitation gauge logs for natural snow, including 954 hours from the 2000-01 data. Freezing rain/drizzle data, based largely on the 1998 ice storm, were used to generate over 235 hours of storm data. Data were acquired from Environment Canada from instruments located at Montreal's Dorval Airport and five other stations in the province of Quebec, Canada. The Dorval Airport data were collected over several winters; data from other stations were collected from the winters of 1997-98 to 2000-01. Similar data were collected for two winters and analyzed by Environment Canada, at Toronto's Pearson Airport. This report includes data on the frequency of deicing under all precipitation conditions at Dorval. Frost and freezing fog deposition rates measured during natural conditions are also reported.

## Results and Conclusions

Based on the data from this study, the precipitation rate ranges currently in use for developing the holdover time tables are satisfactory.

For the several recent winters (1997-98 to 1999-2000), precipitation rates above 25 $g/dm^2/h$ were encountered in all temperature ranges, from above 0°C to the -14°C to -25°C range; the high precipitation rates at cold temperatures were recorded mainly during a few snowstorms in 1998-99. The 95th percentile for precipitation rates was observed to be approximately 22 $g/dm^2/h$ (5 percent of the precipitation rates were above 22 $g/dm^2/h$) for snow. In the -14°C to -25°C range, the 95th percentile was also 22 $g/dm^2/h$. The 95th percentile precipitation rate from the limited freezing rain/drizzle data was approximately 28 $g/dm^2/h$.

During the 1999-2000 winter, precipitation rates of 25 g/dm$^2$/h were encountered in all temperature ranges except -14°C to -25°C. For snow conditions, over 70 percent of precipitation rates were under 10 g/dm$^2$/h, and only 4 percent were above 22 g/dm$^2$/h. In the -14°C to -25°C range, almost 85 percent were under 10 g/dm$^2$/h.

This year's freezing rain/drizzle dataset was based on two main events, and only 7 percent of total precipitation was about 25 g/dm$^2$/h.

The data supplied from CR21X, a newer and modified data logger, require less smoothing and allow for more accurate observation of fluctuating precipitation rates. More data of the type available from the CR21X equipment and from a greater number of winters are needed to confirm the findings. Therefore, the study should be extended in upcoming winters to include data recorded from automated precipitation gauges supported by the Meteorological Service of Canada.

During the 2000-01 winter, tests for collecting frost rates in natural conditions were not conducted; the results and analysis in this report are based on previous tests at Dorval Airport (Appendix H) and Thompson, Manitoba. However, tests on endurance time in simulated frost conditions were carried out between 26 February 2001 and 11 April 2001 at the Institut de recherche d'Hydro-Québec (IREQ) test chamber in Varennes, Quebec. For a full account of these tests, see Transport Canada report TP 13831E, *Endurance Time Tests in Simulated Frost Conditions: 2001*. Based on these trials, several conclusions were drawn: at warmer temperatures, frost conditions were easily produced; at colder temperatures, the required icing intensity was very difficult to achieve.

The Type I and Type II/IV holdover time table formats have undergone significant change since the early 1990s. While the changes have been made primarily to improve and address the safety concerns of many individuals and organizations involved in the deicing industry, a structured approach has not been taken when implementing the changes. In fact, many of the changes have been made on a year-by-year basis at industry meetings. These changes have been typically minor in nature, but after nearly 10 years, the impact on the holdover times has been more significant. More recently, a number of industry members have questioned the suitability of the holdover time table format. Several proposed suggestions for change have been made in order to improve and simplify the tables, while at the same time maintaining a high level of safety. Proposed changes could include new temperature breakdowns to better reflect winter precipitation conditions. Expansion of the snow column would reflect its high usage, as would the removal of unnecessary holdover time ranges in certain columns, resulting in a single value. To substantiate this, Transport Canada has initiated a survey of airlines among several international airports.

# SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a entrepris un programme de recherche visant à faire progresser la technologie du dégivrage et de la protection contre le givre des avions au sol. C'est dans le cadre de ce programme que APS a entrepris une étude rétrospective des données de précipitation (taux de précipitation, température) pour confirmer la pertinence des intensités de précipitations utilisées pour évaluer les durées d'efficacité des liquides antigivre.

Le présent rapport englobe aussi des données colligées à l'occasion d'autres recherches connexes.

L'information contenue dans ce rapport peut servir à évaluer la pertinence d'améliorations possibles à la présentation des tableaux des durées d'efficacité de la SAE.

## Description et traitement des données

Des points de données de précipitations neigeuses ont été établis à partir de relevés nivométriques couvrant un total de 2 998 heures, dont 954 heures pendant l'hiver 2000-2001. Des données de pluie/bruine verglaçante, recueillies pour la plupart au cours de la tempête de verglas de 1998, ont servi à générer des points de données couvrant plus de 235 heures. Ces données, obtenues auprès d'Environnement Canada, provenaient d'instruments situés à l'Aéroport de Dorval, Montréal et de cinq autres stations du Québec, Canada. Les données de l'Aéroport de Dorval couvraient plusieurs hivers, tandis que celles des autres stations ne couvraient que les hivers 1997-1998 à 2000-2001. Des données analogues ont été recueillies et analysées par Environnement Canada à l'Aéroport international Pearson de Toronto pour deux hivers. Ce rapport comprend des données sur la fréquence des opérations de dégivrage dans toutes les conditions de précipitations à l'Aéroport de Dorval. Il comprend aussi les taux de dépôt de givre et de brouillard verglaçant, mesurés en conditions naturelles.

## Résultats et conclusions

Selon les données de la présente étude, les intensités de précipitations actuellement utilisées pour établir les tableaux des durées d'efficacité sont satisfaisantes.

Pour plusieurs des hivers récents (1997-1998 à 1999-2000), des taux de précipitation de plus de 25 g/dm$^2$/h ont été enregistrés dans toutes les plages de températures, de la plus haute (au-dessus de 0 °C) à la plus basse (-14 °C à -25 °C); les taux de précipitation élevés par temps froid ont surtout été enregistrés au cours de quelques tempêtes de neige, à l'hiver 1998-1999. Pour l'ensemble des données concernant les taux de précipitations neigeuses, le 95$^e$ centile était d'environ 22 g/dm$^2$/h (5 p.100 des taux de précipitations étaient au-dessus). Dans la plage de -14 °C à -25 °C, le 95$^e$ centile se situait également à 22 g/dm$^2$/h. Dans la base restreinte de données de pluie/bruine verglaçante, le 95$^e$ centile se situait à environ 28 g/dm$^2$/h.

Au cours de l'hiver 1999-2000, des taux de précipitation de 25 g/dm$^2$/h ont été enregistrés dans toutes les plages de température, sauf dans celle de -14 °C à -25 °C. Pour ce qui est des données sur la neige, plus de 70 p. 100 des taux de précipitation étaient inférieurs à 10 g/dm$^2$/h et seulement 4 p. 100 dépassaient 22 g/dm$^2$/h. Dans la plage des températures de -14 °C à -25 °C, près de 85 p. 100 des taux de précipitation étaient inférieurs à 10 g/dm$^2$/h.

Pour la présente année, l'ensemble de données concernant la pluie/bruine verglaçante provient de deux événements principaux, et seulement 7 p. 100 des taux de précipitation s'établissent à environ 25 g/dm$^2$/h.

Les données fournies par le CR21X, un nouveau type d'enregistreur de données, exigent moins de lissage et permettent une observation plus précise de taux de précipitation fluctuants. Mais il faut acquérir un plus grand nombre de données telles que celles produites par le CR21X, couvrant un plus grand nombre de saisons hivernales, pour confirmer les résultats obtenus. L'étude devrait donc se poursuivre encore quelques hivers, pour permettre l'analyse des données enregistrées par ces appareils automatiques utilisés par le Service météorologique du Canada.

Aucun essai n'a été réalisé pendant l'hiver 2000-2001 pour recueillir des taux de dépôt de givre dans des conditions naturelles; les résultats et les analyses présentés dans le présent rapport ont trait à des essais antérieurs menés à l'Aéroport de Dorval (annexe H) et à Thompson, au Manitoba. Toutefois, des essais d'endurance dans des conditions de givre simulé ont été réalisés du 26 février au 11 avril 2001 dans l'enceinte d'essai de l'Institut de recherche d'Hydro-Québec (IREQ) à Varennes, au Québec. On trouvera un compte rendu complet de ces essais dans le rapport TP 13831E de Transports Canada, intitulé *Endurance Time Tests in Simulated Frost Conditions: 2001*. Plusieurs conclusions ont été tirées de ces essais : aux températures élevées, les conditions de givre étaient faciles à reproduire, mais à basse température, il était très difficile d'atteindre l'intensité de givrage voulue.

La présentation des tableaux des durées d'efficacité des liquides de type I et de types II/IV a beaucoup évolué depuis le début des années 1990. Les changements apportés visaient principalement à améliorer les tableaux et à répondre aux préoccupations de nombreuses personnes et organisations oeuvrant dans le secteur du dégivrage. Mais aucune démarche structurée n'a présidé à ces changements. De fait, beaucoup de changements ont été apportés d'année en année, lors de réunions avec des représentants de l'industrie. Il s'est toujours agi de changements assez mineurs, mais au bout de presque 10 ans, leur effet cumulatif sur les durées d'efficacité est plus marqué. Récemment, des membres de l'industrie ont remis en question la pertinence de la présentation des tableaux des durées d'efficacité. Plusieurs suggestions ont été faites pour améliorer et simplifier les tableaux, tout en maintenant un haut niveau de sécurité. Les changements proposés comprennent de nouvelles plages de températures qui refléteraient mieux les conditions de précipitations hivernales. L'ajout de subdivisions sous la colonne «neige» refléterait l'utilisation intensive de cette colonne, tout comme le remplacement de plages de durées d'efficacité inutiles dans certaines colonnes, par des valeurs uniques. Pour établir le bien-fondé de ces suggestions, Transports Canada a commencé à recueillir l'opinion de compagnies aériennes à plusieurs aéroports internationaux.

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# CONTENTS

1. **INTRODUCTION** .......... 1

2. **METHODOLOGY** .......... 3

- 2.1 Sources of Data and Test Sites .......... 4
- 2.2 Equipment .......... 4
- 2.3 Description of Analytical Methods .......... 7
- 2.4 Linearization of Cumulative Snow Weight Data .......... 7

3. **DESCRIPTION AND PROCESSING OF NATURAL SNOW AND FREEZING RAIN / DRIZZLE DATA** .......... 11

- 3.1 Natural Snow .......... 11
- 3.2 Freezing Rain / Drizzle .......... 13
- 3.3 Temperature – Precipitation Relation for Canadian Stations .......... 16

4. **ANALYSIS AND OBSERVATIONS FOR NATURAL SNOW AND FREEZING RAIN / DRIZZLE** .......... 21

- 4.1 Validity of Gauges for Recording Precipitation Data .......... 21
- 4.2 Natural Snow .......... 28
- 4.3 Snow at Cold Temperatures .......... 29
- 4.4 Comparing MSC with APS 1995 to 2001 Snow Weather Data .......... 32
- 4.5 Comparison of APS 1993 to 1995 with 1995 to 2001 Snow Weather Data .......... 33
- 4.6 Freezing Rain / Drizzle .......... 34
- 4.7 Relation between Weather Data and SAE Holdover Time Tables .......... 34
  - 4.7.1 Number of Frost Deicings at Dorval .......... 36
  - 4.7.2 Number of Deicings for All Conditions at Dorval .......... 36
- 4.8 Potential Changes to the Holdover Time Table Format .......... 42
  - 4.8.1 Type I Fluid HOT Table Situation .......... 42
  - 4.8.2 Evaluation of the Type II/IV HOT Table Temperature Breakdowns .......... 44
  - 4.8.3 Evaluation of Weather Conditions in HOT Tables .......... 45

5. **EVALUATION OF FOG AND FROST DEPOSITION RATES IN NATURAL CONDITIONS** .......... 47

- 5.1 Study to Quantify Freezing Fog Deposition Rates .......... 47
- 5.2 Measurement of Frost Deposition Rates in Natural Conditions .......... 47

6. **CONCLUSIONS** .......... 51

- 6.1 Natural Snow and Freezing Rain / Drizzle .......... 51
- 6.2 Evaluation of Fog Deposition Rates in Natural Condition .......... 51
- 6.3 Evaluation of Frost Deposition Rates .......... 51
- 6.4 Evaluation of HOT Table Format .......... 51

7. **RECOMMENDATIONS** .......... 53

- 7.1 Natural Snow and Freezing Rain / Drizzle .......... 53
- 7.2 Fog Deposition Rates in Natural Condition .......... 53
- 7.3 Frost Deposition Rates .......... 53
- 7.4 HOT Table Format .......... 53

**REFERENCES** .......... 55

## LIST OF APPENDICES

A Work Statement (Excerpt) Project Description

B Winter Weather Data 1995 to 2001

C Snow Weather Data 1993-94 and 1994-95

D Meteorological Service of Canada Study: Frequency of Occurrence of Water Equivalent Precipitation Rates as a Function of Averaging Time, Temperature and Type

E Monthly Meteorological Summary (Montreal - Dorval)

F Experimental Procedure for the Collection of Fog Rates of Deposition in Natural Conditions

G Winter Operations Survey

## LIST OF FIGURES

Figure 2.1: Map of Precipitation Gauge Locations....6
Figure 2.2: CR21X Precipitation Gauge – Cumulative and Linearized Precipitation....9
Figure 3.1: Temperature Distribution Natural Snow – Winter 2000-01....12
Figure 3.2: Temperature Distribution Natural Snow 1995-96 to 2000-01....14
Figure 3.3: Temperature Distribution Freezing Rain/Drizzle 1995-96 to 2000-01....15
Figure 3.4: Temperature Distribution Freezing Rain/Drizzle 2000-01....17
Figure 3.5: Frequency Distributions of Mean Daily Temperature for Halifax in January 1953-1988....19
Figure 3.6: Frequency Distributions of Temperature and Total Precipitation During 2000-01 Winter, Quebec....19
Figure 4.1: READAC and CR21X Analysis – Natural Snow Histogram....23
Figure 4.2: READAC and CR21X Analysis – Natural Snow Chart....23
Figure 4.3: READAC Precipitation Rate, 15 January 1999....25
Figure 4.4: CR21X Precipitation Rate, 15 January 1999....26
Figure 4.5: CR21X Precipitation Rate, 11 January 2001....27
Figure 4.6: 20-Minute Rate Every Minute for All Temperature Ranges....30
Figure 4.7: Subdivision of -14°C to -25°C Snow Data....31
Figure 4.8: Frequency of Frost Deicing....38
Figure 4.9: Frequency of Frost Deicing by Temperature....38
Figure 4.10: Estimate of Frequency of Deicing Operations at Dorval....39
Figure 4.11: Intersection of Wing Temperature and FFP Profiles, OAT -10°C....43
Figure 4.12: Intersection of Wing Temperature and FFP Profiles, OAT -3°C....43
Figure 5.1: Natural Frost Deposition Rates from Montreal 1997-1999 and Thompson 1999-2000....50

## LIST OF TABLES

Table 2.1: Current Rate Limits for Natural Snow....3
Table 2.2: Summary of Weather Data....5
Table 2.3: Sample of Linearized READAC Data....8
Table 3.1: Distribution of Temperature for 2000-01 Winter....11
Table 3.2: Temperature Distribution Over the Past Six Winters....13
Table 3.3: Temperature Distribution for 2000-01 Winter....13
Table 3.4: Temperature Distribution for 2000-01 Winter....16
Table 4.1: Sample of READAC Data and Analysis....22
Table 4.2: 95th Percentile in Each Temperature Range – Natural Snow....28
Table 4.3: Percentage of Heavy Snow Occurrences in Each Temperature Range....28
Table 4.4: Percentage of Heavy Snow Occurrences in Cold Temperatures – Natural Snow....29
Table 4.5: Summary of 1993 to 1995 Snow Weather Data....33
Table 4.6: 95th Percentile in Each Temperature Range – Freezing Rain/Drizzle....34
Table 4.7: Type I Probability of Snow Event in Each Holdover Time Cell....35
Table 4.8: Type II and Type IV Probability of Snow Event in Each Holdover Time Cell....35
Table 4.9: Extract of Dorval Airport Deicing Log....37
Table 4.10: Distribution of Deicing Operations in Montreal for Type I Fluids....40
Table 4.11: Distribution of Deicing Operations in Montreal for Type IV and II Fluids....41
Table 5.1: Summary of Natural Frost Deposition Trials....49

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# GLOSSARY

| | |
|---|---|
| ADM | Aéroports de Montréal |
| APS | APS Aviation Inc. |
| HOT | Holdover Time |
| IREQ | Institut de Recherche d'Hydro-Québec |
| MSC | Meteorological Service of Canada (formerly known as Atmospheric Environment Services) |
| NCAR | National Center for Atmospheric Research |
| OAT | Outside Air Temperature |
| READAC | Remote Environmental Automatic Data Acquisition Concept |
| TDC | Transportation Development Centre |

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# 1. INTRODUCTION

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a study to advance de/anti-icing technology. This report contains the results of an evaluation conducted by APS Aviation between 1995-96 and 2000-01 of precipitation rate data. This study formed part of the 2000-01 winter research program on deicing, as described in Section 5.1.6 of the detailed work statement shown in Appendix A.

Holdover time tables are developed to be used as guidelines by pilots in aircraft departure planning, under different winter weather conditions. Each holdover time table is composed of cells, and each cell contains a holdover time range for a specific temperature range and category of precipitation. The time range in each cell is defined by a "lower" time and an "upper" time; these values represent the failure time of the fluid at the upper and lower precipitation rate range, respectively. Commonly, there are three types of fluid: Type I, Type II, and Type IV.

Aircraft are deiced using heated Type I fluids. Type II and Type IV are anti-icing fluids that are applied following aircraft deicing. Type II fluids are thicker and more viscous than Type I deicing fluids. Type IV fluids are the latest generation of anti-icing fluids and are designed to provide the utmost in holdover time protection. A general format of these tables is shown in Section 4.

Several years ago, holdover times for snow were evaluated or developed using lower and upper precipitation rates of 10 g/dm²/h and 25 g/dm²/h for all air temperatures (0°C, -3°C, -14°C and -25°C). In 1997 at a SAE Workshop Meeting on Laboratory Methods in Montreal, these rates had been considered extreme at temperatures of -14°C and -25°C, because such high precipitation rates, although they do exist, were thought to be less frequent at these lower temperatures. The 1999-2000 Transport Canada report TP 13665E, *Snow Weather Data Evaluation (1995-2000)* (1), concluded that the holdover time rate limits of 10 g/dm²/h and 25 g/dm²/h are representative of natural snow conditions.

The main purpose of this study was to:

- Further evaluate weather precipitation data (precipitation rate/temperature data) over several recent winters and substantiate the suitability of data ranges currently in use for the evaluation of upper and lower holdover time limits. This report encompasses all the data presented in the 1999-2000 Transport Canada report TP 13665E (1).

Secondary objectives were to conduct fog deposition measurements outdoors, using a procedure devised during the past year, and thus establish the range of fog deposition rates that occur in natural conditions, and to collect frost deposition rates in natural conditions and cold temperatures to establish a deposition range for these conditions.

Data on the frequency of frost, freezing fog, and frost deposition rates measured in natural conditions are included in Section 5.

## 2. METHODOLOGY

This section describes the methods used to evaluate weather data collected to study the occurrence of high precipitation rates at low temperatures for natural snow and freezing rain/drizzle.

Holdover time tables were generated from data collected during the 2000-01 winter test season. These tables, as well as descriptions of precipitation types, precipitation rates, rate limits, and the methods used to calculate holdover times, are presented in Transport Canada report TP 13826E, *SAE Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000-2001 Winter* (2).

At the SAE Workgroup on Laboratory Methods, held in Montreal in 1997 (3), a revision of the holdover time table guidelines was proposed. It was suggested that the upper and lower precipitation rate limits for snow be reduced, because there is a natural tendency toward reduced precipitation rates as the outside air temperature drops; it is generally contended that rate limits should reflect natural conditions as closely as possible.

The possibility of maintaining currently accepted precipitation rate limits for snow was considered. However, based on the data presented in Transport Canada report TP 13665E (1), the rate limits remained as shown in Table 2.1.

**Table 2.1: Current Rate Limits for Natural Snow**

| Temperature Range | Holdover Time Evaluation Temperature | Precipitation Rate (g/dm²/h) | |
|---|---|---|---|
| | | Accepted Upper Limit | Accepted Lower Limit |
| -3 to -14°C | -14°C | 25 | 10 |
| -14 to -25°C | -25°C | 25 | 10 |
| Below -25°C | (TBD by event) | 25 | 10 |

The data generated in the current report are intended to support the above accepted precipitation rate limits.

Another argument to maintain the rates of 10 g/dm²/h and 25 g/dm²/h at cold temperatures is that this is the meteorological definition that is accepted. Pilots have the tools to determine the condition of light, moderate or heavy snow based on these definitions. A change from this could add some confusion. In any case, if the frequency of high precipitation (above 25 g/dm²/h) is low at cold temperatures (below -14°C), then the number of actual operations would also be low.

## 2.1 Sources of Data and Test Sites

The precipitation rates analyzed in this report were extracted from the following:

- The Dorval READAC log for the years 1995 to 1999.
- The data logs from 1998 to 2001 for three CR21X stations at Rouyn, Pointe-au-Père (Mont-Joli), and Ancienne Lorette (Quebec City).
- The data log from the Dorval Airport CR21X station from 1998 to 2001.
- The data logs for 2000 and 2001 from two additional stations located in High Falls (near Ottawa, Ontario) and Frelighsburg (in Quebec's Eastern Townships).

In addition, data has been collected by APS Aviation Inc. from various sources dating back to the 1990-91 winter season, using different precipitation gauges, as shown in Table 2.2. Data from these sources are analyzed in Appendices C and D.

Each site is identified on a map of Quebec, shown in Figure 2.1. The data are included in Appendix B. Furthermore, two similar studies were conducted in 1995-96. One study was conducted by APS using data collected from three weather stations located around Montreal (included in Appendix C). The Meteorological Service of Canada (MSC) carried out a similar study using data collected at Lester B. Pearson International Airport in Toronto (included in Appendix D).

## 2.2 Equipment

The Remote Environmental Automatic Data Acquisition Concept (READAC) precipitation gauge consists of a bucket partially filled with an antifreeze compound so that it effectively captures snow. A weighing transducer provides instantaneous displacement values of the bucket in terms of millimetres of precipitation. This shaft displacement is transmitted every 2.5 seconds and averaged every minute in an attempt to eliminate spurious data caused by wind pumping and temperature-induced contraction and expansion of the sensor. The READAC instrument has a resolution of 0.5 mm (5 g/dm$^2$).

The CR21X station operates on the same principle as the READAC station and has an accuracy of 0.1 mm (1 g/dm$^2$). The station measures precipitation with a Fisher Porter precipitation gauge, and the readings are logged with a CR21X data logger.

## Table 2.2: Summary of Weather Data

| PROJECT # | YEAR | PLATE PAN | READAC YUL | CR21X | | | | | | CITY OF MONTREAL (Fisher/Porter) | OMBROMETER THIES | ETI | TIPPING BUCKET | YYZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | WUY (Rouyn) | WTQ (Dorval) | WQB (Quebec City) | WYQ (Pointe-au-Père) | WFQ (Frelighsburg) | XHF (High Falls) | | | | | |
| | 1990-91 | Test period | | | | | | | | | | | x(3) | |
| | 1991-92 | Test period | | | | | | | | x(5) | x(3) | | | |
| | 1992-93 | Test period | | | | | | | | x(5) | x(3) | | | |
| C1171 | 1993-94 | Test period | | | | | | | | x(1)<br>(Three stations) | x(3)<br>(Shielded) | | | |
| CM1222 | 1994-95 | Test period | x(1) | | | | | | | | | | | |
| CM1283 | 1995-96 | 15 min | x(1) | | | | | | | | | x | | x(4) |
| CM1338 | 1996-97 | 15 min | x(6) | | x(6) | | | | | | | | | x(4) |
| CM1380 | 1997-98 | 5-15 min | x(2) | x(2) | x(2) | x(2) | x(2) | | | | | | | |
| CM1514 | 1998-99 | 5-15 min | x(2) | x(2) | x(2) | x(2) | x(2) | | | | | | | |
| CM1589 | 1999-2000 | 5-15 min | | x(2) | x(3) | x(2) | x(2) | x(2) | x(2) | | | | | |
| CM1680 | 2000-01 | 5-15 min | | x(2) | x(2) | x(2) | x(2) | x(2) | x(2) | | | | | |

(1) Data analysed for Transport Canada in 1996

(2) Data used for this report

(3) Unusable data - precipitation rate determined by this gauge was always lower than other instruments

(4) Analysis completed by AES at YYZ

(5) Unusable data - scattered data (gauge was not shielded)

(6) Data archived

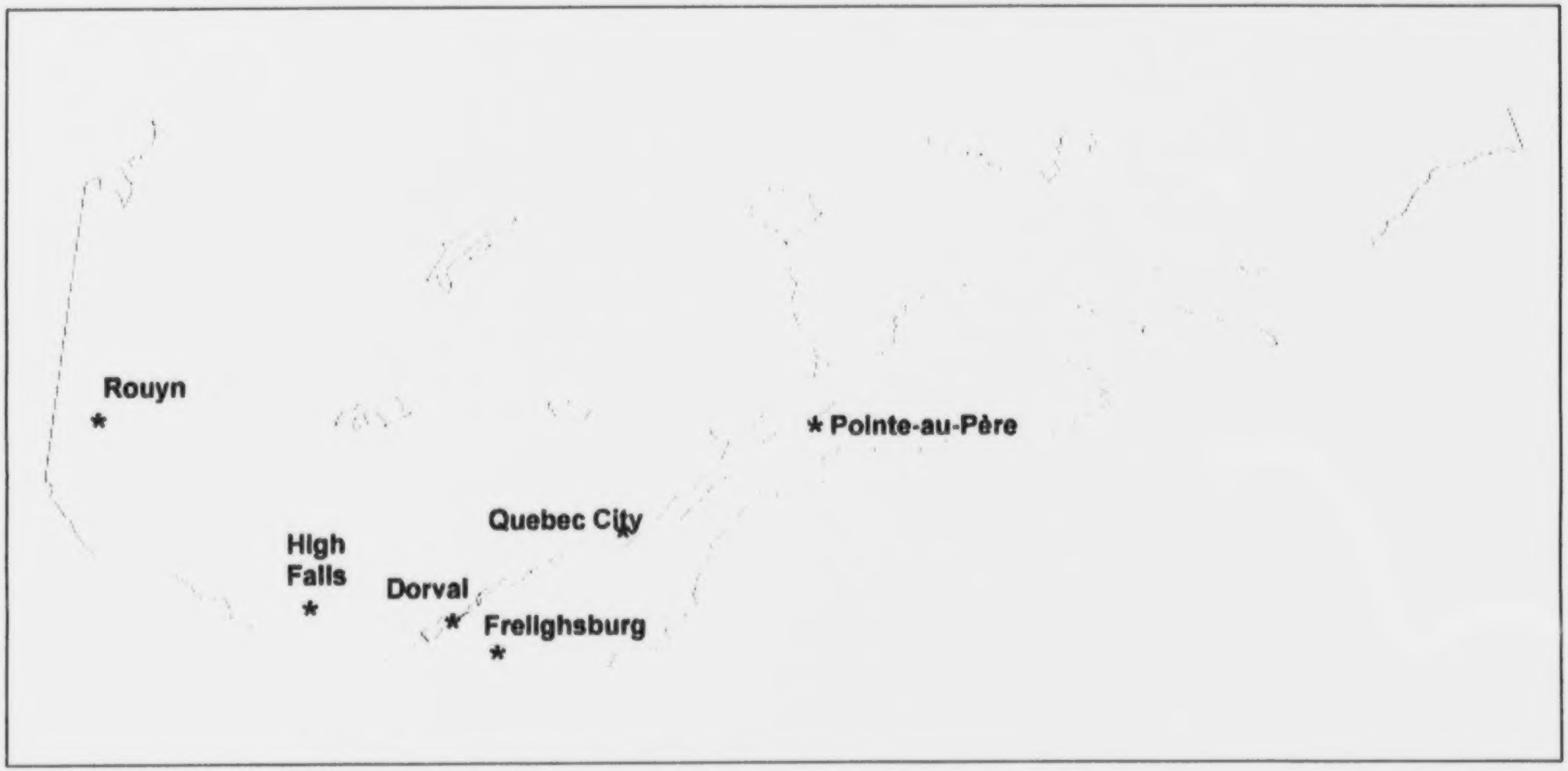
Rouyn
High Falls
Dorval
Quebec City
Frelighsburg
Pointe-au-Père

Figure 2.1: Map of Precipitation Gauge Locations

Precipitation rates tend to fluctuate rapidly during snowstorms. The weight resolution of the READAC stations is less accurate in measuring rapid changes. The data from the CR21X station requires less smoothing before it can be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods with heavy precipitation.

## 2.3 Description of Analytical Methods

Precipitation rate data were averaged at intervals that correspond to three specified periods typically used in the holdover time tables: 6 minutes for Type I fluids, 20 for Type II, and 35 for Type IV. For natural snow, data were classified into four temperature ranges: above 0°C, 0°C to -3°C, -3°C to -14°C, and -14°C to -25°C. For freezing rain/drizzle, data were classified into two ranges: 0°C to -3°C and -3°C to -10°C.

Snowfalls at Dorval were tracked from 1995 to 2001 using the Monthly Meteorological Data Summary provided by Environment Canada. This summary includes meteorological data such as temperature, wind speeds and directions, dew point temperatures and humidity on an hourly basis, and precipitation type and total accumulation on a daily basis.

An example of the Monthly Meteorological Summary for Montreal is included in Appendix E. The last page of the summary (E-6) describes whether it snowed on a particular day, and the first page (E-1) provides total snow accumulation for each day. Based on this information, the precipitation and temperature data were then extracted from READAC logs on a minute-by-minute basis, and added to a database. The CR21X data were treated in a similar way.

Periods of snowfall were identified using Environment Canada summaries, and snow accumulation data were added to the database along with ambient air temperatures. The six CR21X data loggers (at Rouyn, Pointe-au-Père, Ancienne Lorette, Dorval, High Falls, and Frelighsburg) provided temperatures on an hourly basis. The temperatures were then linearly interpolated throughout the hour on a minute-by-minute basis.

## 2.4 Linearization of Cumulative Snow Weight Data

Using an algorithm developed by APS, the total precipitation for each snowfall was linearized to produce a smooth curve. An example of how the algorithm linearizes data is shown in Table 2.3. Figure 2.2 shows an output from the CR21X data logger recording the output from the precipitation

## Table 2.3: Sample of Linearized READAC Data

| Location | Date | Zulu Time | Temp (°C) | Type of Precip. | Total Snow Accumulation (g/dm²) | Linearized Total Snow Accumulation (g/dm²) | | Precipitation Rate (g/dm²/h) Moving Average Intervals 6 min | 20 min | 35 min |
|---|---|---|---|---|---|---|---|---|---|---|
| YUL | 14/12/1995 | 21:16 | -11.8 | S- | 40 | 40.00 | | ( a ) | ( b ) | ( c ) |
| YUL | 14/12/1995 | 21:17 | -11.7 | S- | 40 | 40.16 | | 9.38 | 9.38 | [illegible]32 |
| YUL | 14/12/1995 | 21:18 | -11.6 | S- | 40 | 40.31 | | 9.38 | 9.38 | [illegible]56 |
| YUL | 14/12/1995 | 21:19 | -11.6 | S- | 40 | 40.47 | | 9.38 | 9.38 | [illegible]79 |
| YUL | 14/12/1995 | 21:20 | -11.6 | S- | 40 | 40.63 | | 9.38 | 9.38 | [illegible]03 |
| YUL | 14/12/1995 | 21:21 | -11.6 | S- | 40 | 40.78 | | 9.38 | 9.38 | [illegible]27 |
| YUL | 14/12/1995 | 21:22 | -11.6 | S- | 40 | 40.94 | | 9.38 | 9.38 | [illegible]50 |
| YUL | 14/12/1995 | 21:22 | -11.5 | S- | 40 | 41.09 | | 9.38 | 9.38 | [illegible]74 |
| YUL | 14/12/1995 | 21:23 | -11.6 | S- | 40 | 41.25 | | 9.38 | 9.38 | [illegible]97 |
| YUL | 14/12/1995 | 21:24 | -11.6 | S- | 40 | 41.41 | | 9.38 | 9.38 | [illegible]21 |
| YUL | 14/12/1995 | 21:24 | -11.4 | S- | 40 | 41.56 | | 9.38 | 9.38 | [illegible].45 |
| YUL | 14/12/1995 | 21:25 | -11.4 | S- | 40 | 41.72 | | [illegible] | 9.38 | [illegible].68 |
| YUL | 14/12/1995 | 21:25 | -11.5 | S- | 40 | 41.88 | | 9.38 | 9.38 | [illegible]2.92 |
| YUL | 14/12/1995 | 21:26 | -11.5 | S- | 40 | 42.03 | | 9.38 | 9.79 | 13.16 |
| YUL | 14/12/1995 | 21:26 | -11.4 | S- | 40 | 42.19 | | 9.38 | 10.20 | 13.39 |
| YUL | 14/12/1995 | 21:27 | -11.4 | S- | 40 | 42.34 | | 9.38 | 10.62 | 13.48 |
| YUL | 14/12/1995 | 21:28 | -11.4 | S- | 40 | 42.50 | | 9.38 | 11.03 | 13.57 |
| YUL | 14/12/1995 | 21:29 | -11.4 | S- | 40 | 42.66 | | 9.38 | 11.4[illegible] | 13.66 |
| YUL | 14/12/1995 | 21:30 | -11.4 | S- | 40 | 42.81 | | 9.38 | [illegible] | 13.75 |
| YUL | 14/12/1995 | 21:31 | -11.4 | S- | 40 | 42.97 | | [illegible] | 12.27 | 13.84 |
| YUL | 14/12/1995 | 21:31 | -11.3 | S- | 40 | 43.13 | | 9.38 | 12.68 | 13.93 |
| YUL | 14/12/1995 | 21:32 | -11.3 | S- | 40 | 43.28 | | 9.38 | 13.10 | 14.02 |
| YUL | 14/12/1995 | 21:32 | -11.4 | S- | 40 | 43.44 | | 9.38 | 13.51 | 14.11 |
| YUL | 14/12/1995 | 21:33 | -11.4 | S- | 40 | 43.59 | | 9.38 | 13.92 | 14.20 |
| YUL | 14/12/1995 | 21:33 | -11.3 | S- | 40 | 43.75 | | 9.38 | 14.34 | 14.29 |
| YUL | 14/12/1995 | 21:34 | -11.3 | S- | 40 | 43.91 | | 9.38 | 14.75 | 14.38 |
| YUL | 14/12/1995 | 21:34 | -11.3 | S- | 40 | 44.06 | | 9.38 | 15.17 | 14.46 |
| YUL | 14/12/1995 | 21:35 | -11.3 | S- | 40 | 44.22 | | 10.75 | 15.58 | 14.55 |
| YUL | 14/12/1995 | 21:35 | -11.2 | S- | 40 | 44.38 | | 12.13 | 15.99 | 14.64 |
| YUL | 14/12/1995 | 21:36 | -11.2 | S- | 40 | 44.53 | | 13.51 | 16.41 | 14.73 |
| YUL | 14/12/1995 | 21:36 | -11.2 | S- | 40 | 44.69 | | 14.89 | 16.56 | 14.82 |
| YUL | 14/12/1995 | 21:37 | -11.2 | S- | 40 | 44.84 | | 16.27 | 16.72 | 14.91 |
| YUL | 14/12/1995 | 21:37 | -11.2 | S- | 45 | 45.00 | | 17.65 | 16.88 | 15.00 |
| YUL | 14/12/1995 | 21:38 | -11.2 | S- | 45 | 45.29 | | 17.65 | 16.62 | 14.85 |
| YUL | 14/12/1995 | 21:39 | -11.2 | S- | 45 | 45.59 | | 17.65 | 16.36 | 14.71 |
| YUL | 14/12/1995 | 21:40 | -11.2 | S- | 45 | 45.88 | | 17.65 | 16.10 | 14.56 |
| YUL | 14/12/1995 | 21:41 | -11.1 | S- | 45 | 46.18 | | 17.65 | 15.85 | 14.41 |
| YUL | 14/12/1995 | 21:42 | -11.1 | S- | 45 | 46.47 | | 17.65 | 15.59 | 14.26 |
| YUL | 14/12/1995 | 21:43 | -11.1 | S- | 45 | 46.76 | | 17.65 | 15.33 | 14.12 |
| YUL | 14/12/1995 | 21:44 | -11.1 | S- | 45 | 47.06 | | 17.65 | 15.07 | 14.18 |
| YUL | 14/12/1995 | 21:45 | -11.1 | S- | 45 | 47.35 | | 17.65 | 14.82 | 14.25 |
| YUL | 14/12/1995 | 21:46 | -11.1 | S- | 45 | 47.65 | | 17.65 | 14.56 | 14.32 |
| YUL | 14/12/1995 | 21:47 | -11.1 | S- | 45 | 47.94 | | 17.65 | 14.30 | 14.39 |
| YUL | 14/12/1995 | 21:47 | -11.0 | S- | 45 | 48.24 | | 17.65 | 14.04 | 14.45 |
| YUL | 14/12/1995 | 21:48 | -11.0 | S- | 45 | 48.53 | | 16.79 | 13.79 | 14.52 |
| YUL | 14/12/1995 | 21:49 | -11.0 | S- | 45 | 48.82 | | 15.93 | 13.53 | 14.59 |
| YUL | 14/12/1995 | 21:50 | -11.0 | S- | 45 | 49.12 | | 15.07 | 13.27 | 14.66 |
| YUL | 14/12/1995 | 21:51 | -11.0 | S- | 45 | 49.41 | | 14.22 | 13.01 | 14.72 |
| YUL | 14/12/1995 | 21:52 | -10.9 | S- | 45 | 49.71 | | 13.36 | 12.76 | 14.79 |
| YUL | 14/12/1995 | 21:53 | -10.8 | S- | 50 | 50.00 | | 12.50 | 12.50 | 14.86 |

( a ) = (40.94 - 40.00)*60 / 6
( b ) = (43.13 - 40.00)*60 / 20
( a ) = (45.88 - 40.00)*60 / 35

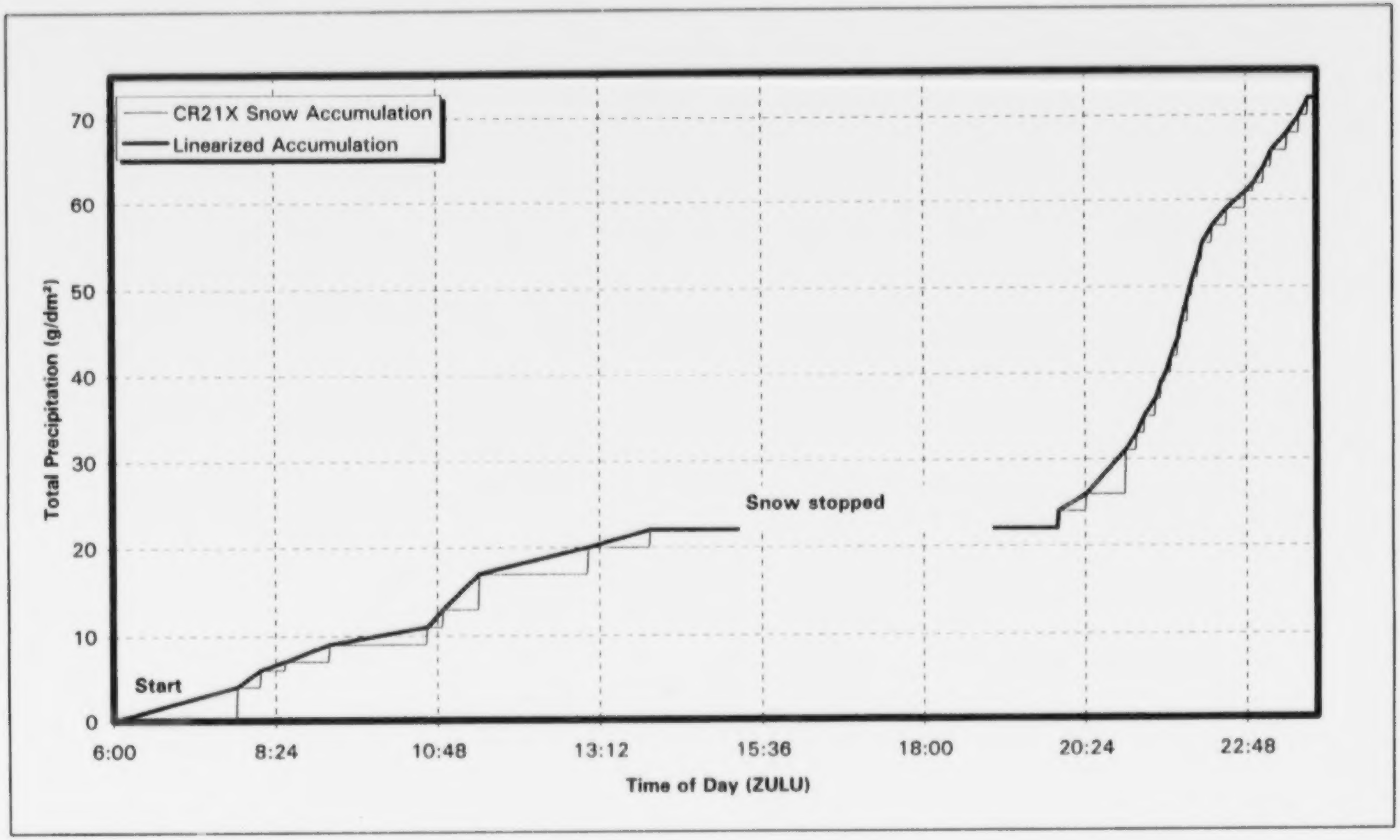

Figure 2.2: CR21X Precipitation Gauge – Cumulative and Linearized Precipitation

gauges and the linearized data for a typical snowfall. The precipitation gauge output, sensitive to 1 g/dm², is plotted versus time to establish the periods of snowfalls. As shown in Figure 2.2, the period when snowfalls were interrupted for a long time was excluded from the analysis. Subsequent snowfalls were treated similarly. The first and last indications of snowfall (first and last 1 g/dm²) were excluded due to uncertainty about the precise start and end of the snowfall.

Periods of low-rate snow precipitation might have been overlooked due to long interruptions in bucket weight changes. It is difficult to establish whether these weight changes were due to constant low rate precipitation or long periods with no precipitation and short intervals of higher precipitation near the time of weight changes. The start and end of a snowstorm are difficult to establish, because the snow might have started and ended gradually at slow rates or abruptly at high rates. For the past several recent winters, light snowfalls over long periods of time were excluded. For the last winter, it was established, as a rule, that snowfalls with a total precipitation of 2 cm over 6 hours were excluded. This would become the analytical pattern for successive years.

The READAC and CR21X data loggers record the bucket weight each minute. Precipitation rates are calculated according to the bucket weight and the time between readings. For each interval, the rate is calculated every minute using Equation 1.:

$$Rate_i = \frac{W_i - W_{i-1}}{\Delta time} \qquad (1)$$

Where:

| | |
|---|---|
| $Rate_i$ | is the rate at a given time |
| $W_i$ | is the linearized bucket weight at that time |
| $W_{i-1}$ | is the linearized bucket weight one time interval before the given time |
| $\Delta time$ | is the length of the time interval (6, 20, or 35 minutes) |

A temperature was associated with the rate based on the time and day at which the rate was measured. All rate and temperature data were added to a database, which contains calculated precipitation rates classified by ambient temperature for all sites included in the study. The database was then sorted by temperature range (Above 0°C, 0°C to -3°C, -3°C to -14°C, and -14°C to -25°C), and the probability for each precipitation rate at each temperature range was calculated using histograms and cumulative percentage.

# 3. DESCRIPTION AND PROCESSING OF NATURAL SNOW AND FREEZING RAIN / DRIZZLE DATA

## 3.1 Natural Snow

In total, 57 280 data points were collected for natural snow conditions during the 2000-01 season at the six stations in Quebec. This represents over 950 hours of snowfall and an average of approximately 160 hours of snowfall at each station. Due to improvements in the CR21X stations, most data collected during the past winter were usable in this analysis. The Dorval and Frelighsburg data for 2000-01 were not available for the whole winter due to some technical problems. The distribution of new data points from all stations, sorted by temperature, is listed in Table 3.1.

**Table 3.1: Distribution of Temperature for 2000-01 Winter**

| Temperature Range | # of Data Points (2000-01) |
|---|---|
| Above 0°C | 7 752 |
| Between 0°C and -3°C | 13 595 |
| Between -3°C and -7°C | 21 323 |
| Between -7°C and -14°C | 12 723 |
| Between -14°C and -25°C | 1887 |
| **Total** | 57 280 |

The distribution of data points for 2000-01, by temperature and in histogram format, is shown in Figure 3.1. The following observations should be noted:

- 13.5 percent of the snowfalls occurred above 0°C.
- 23.7 percent of the snowfalls occurred within the range of 0°C to -3°C.
- 37.2 percent occurred between -3°C and -7°C.
- 22.3 percent occurred between -7°C and -14°C.
- 3.3 percent occurred between -14°C and -25°C.

A total of 179 907 data points were collected for natural snow conditions from 1995-96 to 2000-01. This represents on average, approximately 100 hours of snowfall per year for each of the six stations in Quebec. The distribution of data points, by temperature range, is listed in Table 3.2.

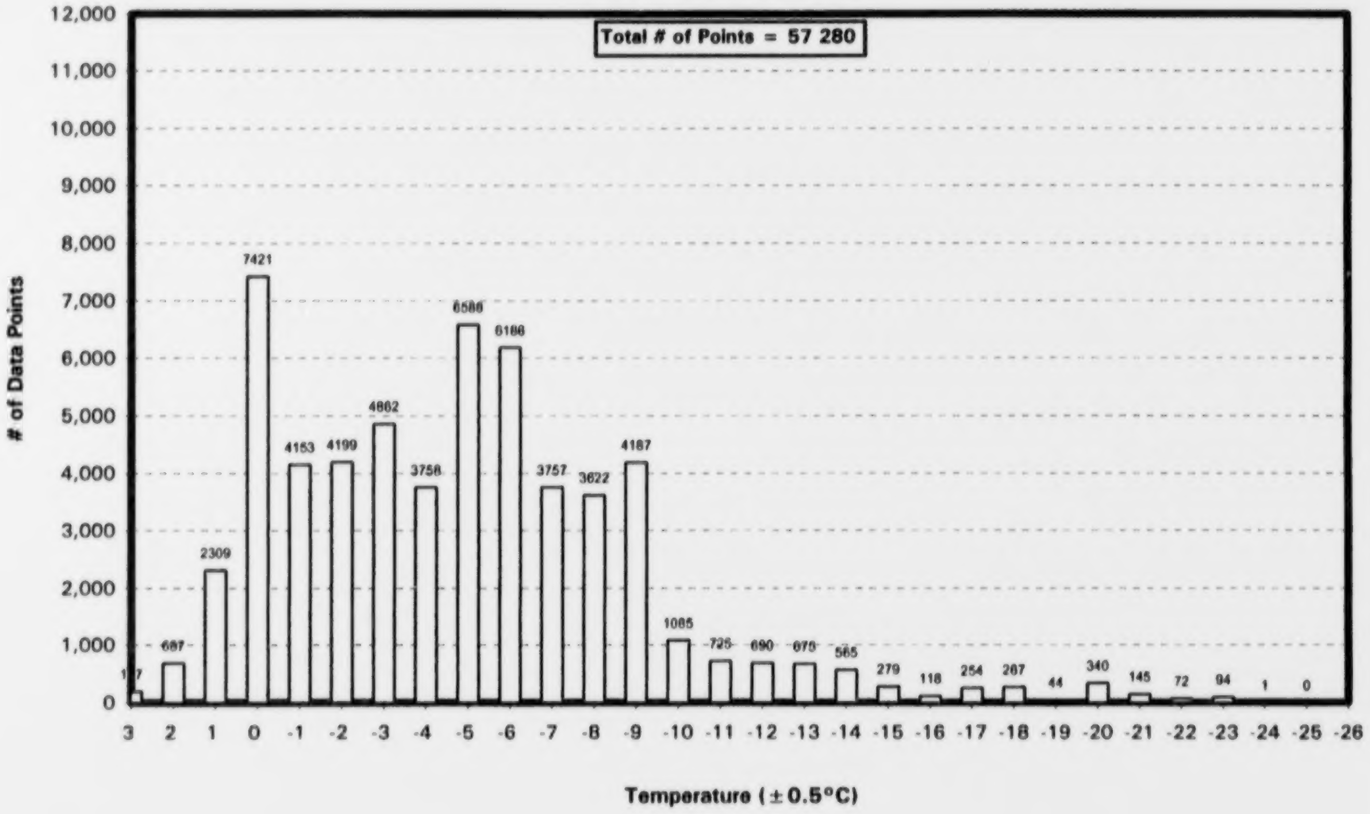

Figure 3.1: Temperature Distribution Natural Snow – Winter 2000-01

**Table 3.2: Temperature Distribution Over the Past Six Winters**

| Temperature Range | # of Data Points (1995-96 to 2000-01) |
|---|---|
| Above 0°C | 17 144 |
| Between 0°C and -3°C | 41 717 |
| Between -3°C and -7°C | 57 701 |
| Between -7°C and -14°C | 52 076 |
| Between -14°C and -25°C | 11 269 |
| **Total** | 179 907 |

Figure 3.2 shows the breakdown of total data points collected from 1995-96 to 2000-01, by temperature for natural snow. The following observations should be noted:

- 9.5 percent of the snowfalls occurred above 0°C temperature.
- 23.2 percent of the snowfalls occurred within the range of 0°C to -3°C.
- 32.0 percent occurred between -3°C and -7°C.
- 29.0 percent occurred between -7°C and -14°C.
- 6.3 percent occurred between -14°C and -25°C.

## 3.2 Freezing Rain / Drizzle

Freezing rain/drizzle data were developed from READAC logs, based largely on the January 1998 ice storm, for a total of 14 196 data points. This represents approximately 236 hours of light freezing rain/drizzle data. The distribution of these data, by temperature range, is shown in Figure 3.3 and summarized by temperature range in Table 3.3.

**Table 3.3: Temperature Distribution for 2000-01 Winter**

| Temperature Range | # of Data Points |
|---|---|
| Above 0°C | 2 896 |
| Between 0°C and -3°C | 4 123 |
| Between -3°C and -10°C | 7 177 |
| **Total** | 14 196 |

The following observations should be noted:

- Freezing rain/drizzle did not occur at temperatures below -9°C.
- Over 50 percent of the freezing rain/drizzle occurred at temperatures between -3°C and -9°C.

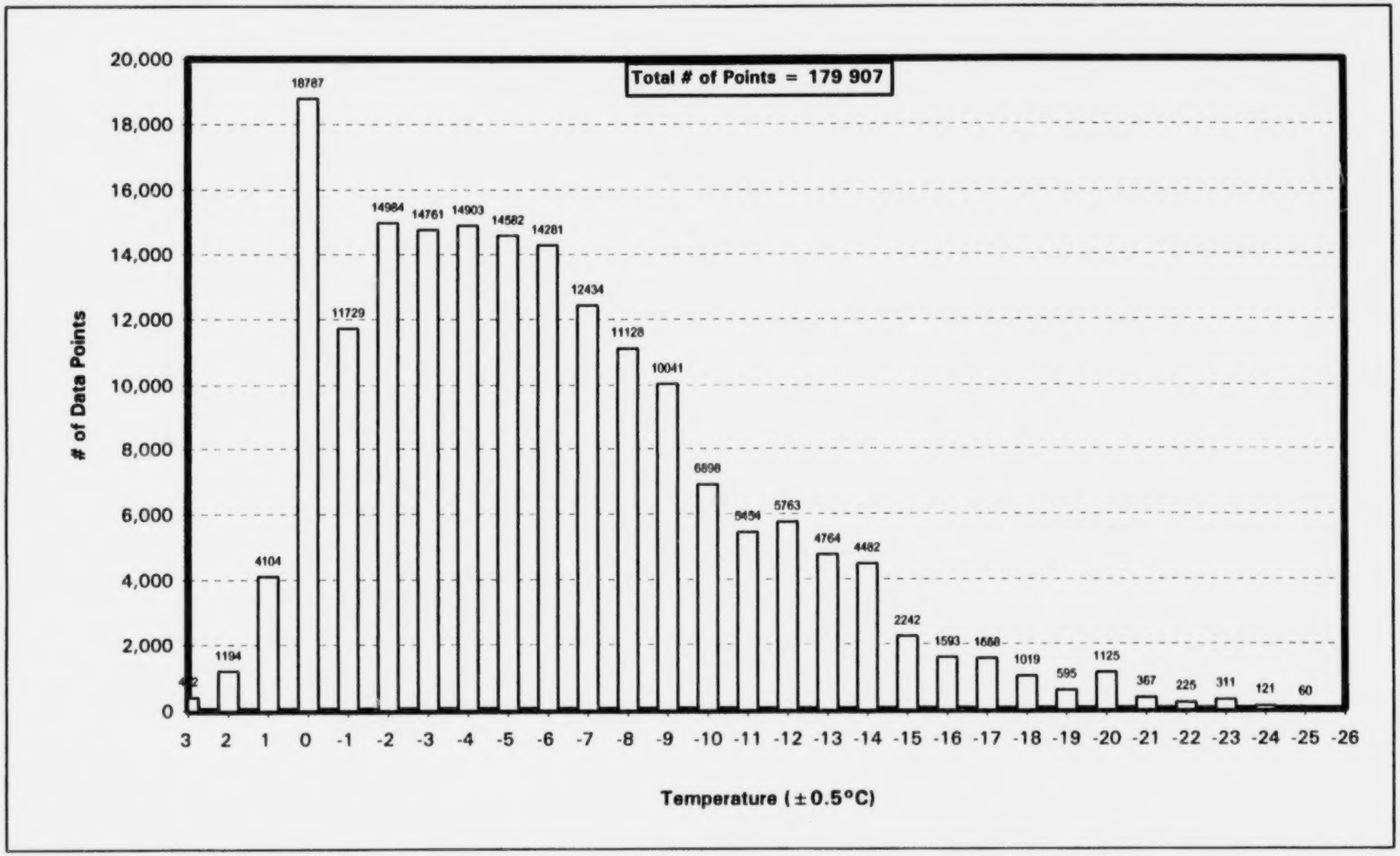

Figure 3.2: Temperature Distribution Natural Snow 1995-96 to 2000-01

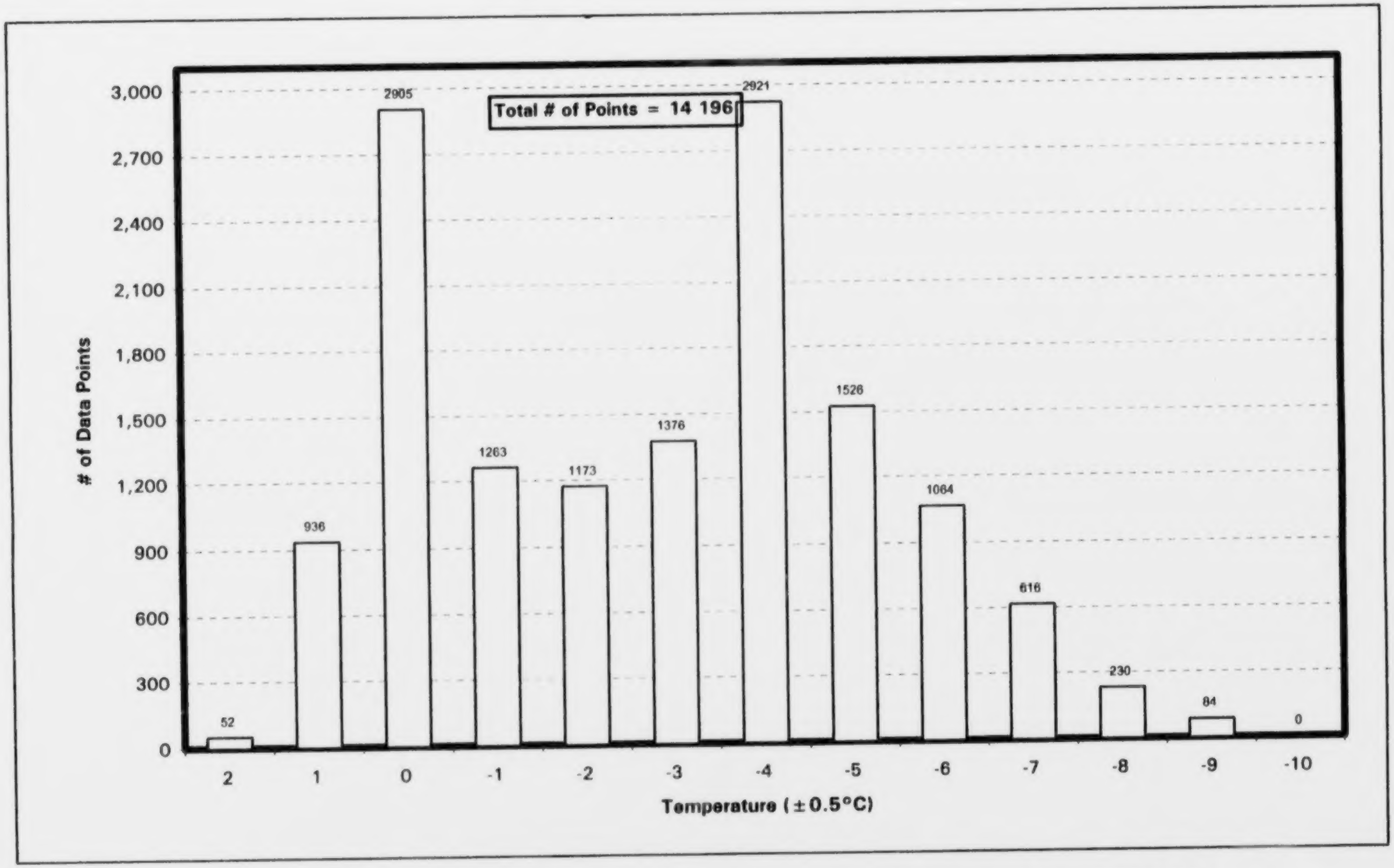

Figure 3.3: Temperature Distribution Freezing Rain/Drizzle 1995-96 to 2000-01

These observations should not be used as a generalization of freezing rain/drizzle occurrences, because most of the data were limited to the January 1998 ice storm.

For Dorval and the five other Quebec stations, only 785 data points were collected during the 2000-01 winter due to some recording device malfunctions. These represent approximately 13 hours of freezing rain/drizzle data. The distribution of these data, by temperature range, is shown in Figure 3.4 and summarized by temperature range in Table 3.4.

**Table 3.4: Temperature Distribution for 2000-01 Winter**

| Temperature Range | # of Data Points |
|---|---|
| Above 0°C | 311 |
| Between 0 and -3°C | 217 |
| Between -3°C and -10°C | 257 |
| **Total** | 785 |

The following observation should be noted:

- Freezing rain/drizzle did not occur at temperatures below -6°C.

## 3.3 Temperature – Precipitation Relation for Canadian Stations

Several reports have been published on temperature relationships and the occurrence of precipitation (4, 5, 6, 7, 8, 9).

Temperature and precipitation are two of the most important variables describing our climate. The dependence of daily precipitation on average daily temperature has been examined for all seasons, using climatological data from 56 stations across Canada in a study published in *The Journal of Climate* on 20 November 1991 (6).

According to that study, the relation between these two factors is important for several reasons. First, precipitation-forming processes could be identified from any relations observed. Second, if they are closely linked, an effective weather forecasting aid could be developed. Third, predictions of climate temperature changes might be used to predict precipitation changes.

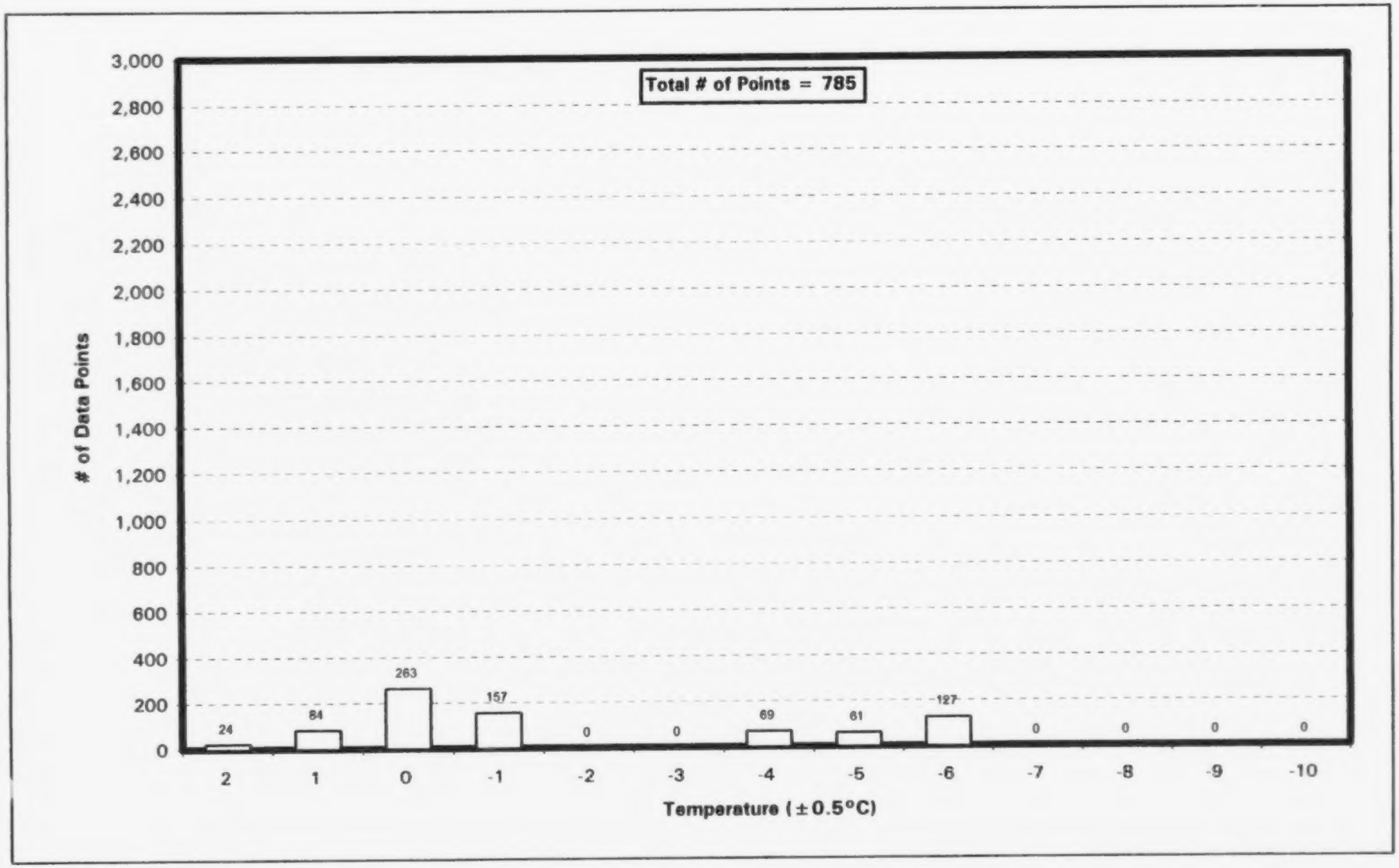

Figure 3.4: Temperature Distribution Freezing Rain/Drizzle 2000-01

The 56 stations were chosen because they contained long records (over 40 years) and were distributed across the area of interest. For every month, for each degree to the mean daily temperature, the distribution of precipitation amounts was calculated for the entire station record. These data were then processed and the appropriate graphs compiled.

For example, Figure 3.5 shows the 1953-1958 frequency distributions of mean daily air temperature for Halifax in January. The distribution of total precipitation as a function of mean daily temperature is superimposed. As is evident from this graph, precipitation was observed on relatively warm days during the winter. The fraction of total precipitation occurring at temperatures below median daily temperature was only 20 percent.

As shown in the study, this is a consistent pattern across the country (with a few exceptions when this dependence is influenced by geography, as seen in the coastal areas and near the Rocky Mountains).

Using the same procedure, APS analyzed the dataset from winter 2000-01 for six stations in Quebec (Quebec, Montreal, Rouyn Noranda, Pointe-au-Père, High Falls and Frelighsburg). The period taken into consideration was December 2000 to March 2001. Because the duration of measurements was very short in comparison with the MSC study, a mean daily temperature for the whole season was calculated by averaging the mean daily temperatures for each day of this period. The results are shown graphically in Figure 3.6.

As can be seen, the Quebec stations closely follow the pattern for the rest of Canada. For these six measuring points, 89 percent of the precipitation occurred at a temperature above the median.

The Canadian dataset shows that 20 percent of precipitation occurs below the median temperature. In the case of Quebec, only 11 percent occurs below it. If the median temperature for Quebec (-8.8°C) were the same as for Canada (-5.9°C), then the percent of precipitation below the median would be very similar.

Based on this analysis, the Quebec dataset could be considered a small-scale representation of the Canadian one.

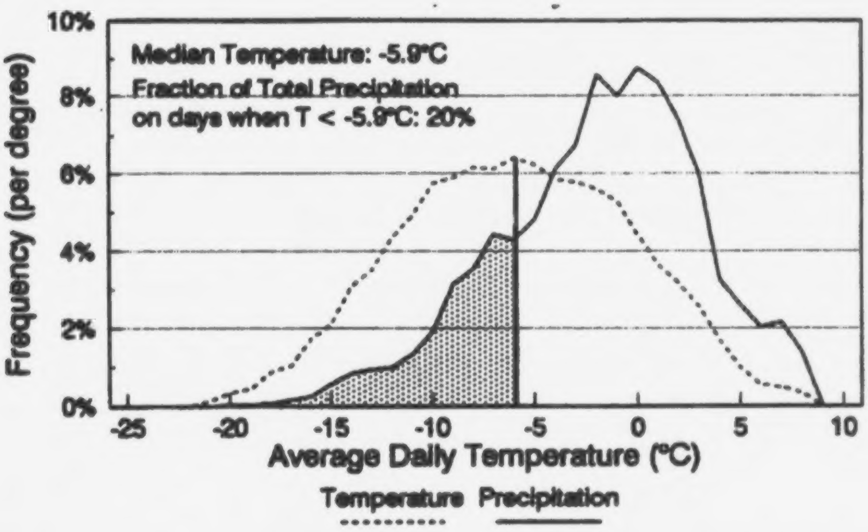

Figure 3.5: Frequency Distributions of Mean Daily Temperature for Halifax in January 1953-1988

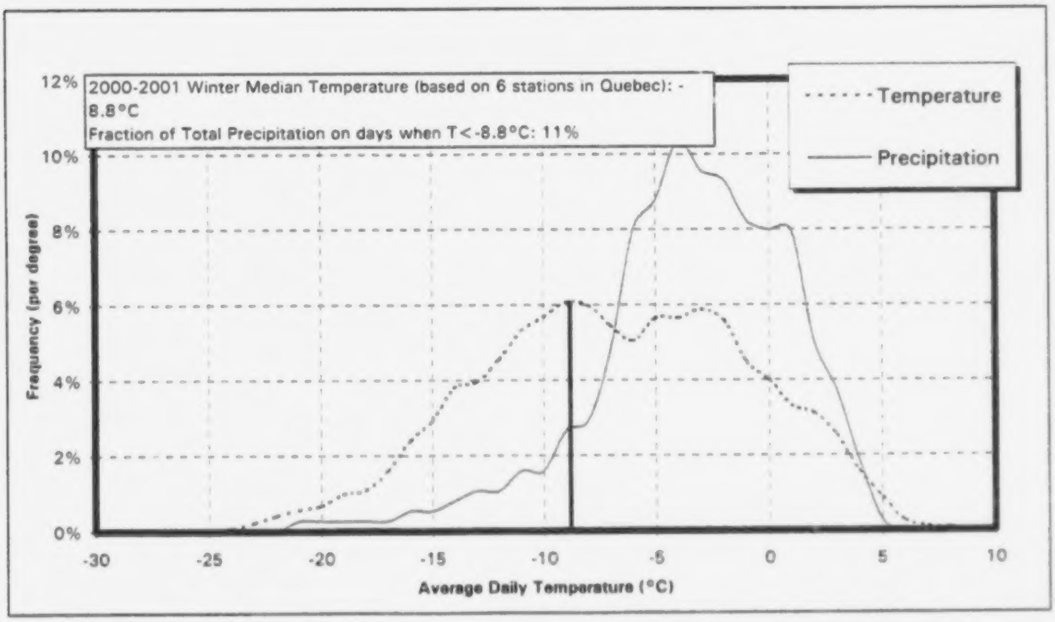

Figure 3.6: Frequency Distributions of Temperature and Total Precipitation During 2000-01 Winter, Quebec

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# 4. ANALYSIS AND OBSERVATIONS FOR NATURAL SNOW AND FREEZING RAIN / DRIZZLE

Precipitation rates were calculated from the weather data at 6-, 20-, and 35-minute intervals using a moving average calculated on a minute-by-minute basis. Table 4.1 shows minute-by-minute READAC data at Dorval Airport for a 37-minute period on 14 December 1995. Also shown are the 6-minute, 20-minute, and 35-minute averages computed using the linearized accumulation. The average snow rates, used as point data, were calculated by taking the snow accumulation during a specific time interval and dividing it by the interval. The three intervals used for this analysis are represented in Table 4.1 by brackets in the column next to "Linearized Total Snow Accumulation". The average snow rate was re-calculated every minute by moving the brackets down one time interval (one minute).

The snow weather data were plotted in two formats. In one, the number of snow precipitation events was plotted against the precipitation rates (Figure 4.1). The other (Figure 4.2) plots the cumulative probability of snow over all possible precipitation rates. The figures shown correspond to the temperature range of -3°C to -7°C for 20-minute rate calculations. Both graphs used the corresponding period to calculate average precipitation rates.

A complete set of graphs for all temperature ranges and rate durations for natural snow and freezing rain/drizzle is included in Appendix B.

The histogram in Figure 4.1 indicates that snow events with low precipitation rates occurred much more frequently than those with high precipitation rates for the temperature range shown.

The cumulative probability in Figure 4.2 indicates that over 96 percent of all the natural snow events in the data had precipitation rates below 25 $g/dm^2/h$ for 20-minute rate intervals.

The 95th percentile criterion was used in the analysis conducted by MSC in 1995 to establish the frequency of precipitation rates. The same criterion was used by APS. Results are described in the following subsections.

## 4.1 Validity of Gauges for Recording Precipitation Data

The objective of this part of the study was to evaluate precipitation rates measured with the automated gauges used in this study and compare them with the plate pans used for measuring rates for HOT (holdover time).

## Table 4.1: Sample of READAC Data and Analysis

| Location | Date | Zulu Time | Temp (°C) | Type of Precip. | Total Snow Accumulation (g/dm²) | Linearized Total Snow Accumulation (g/dm²) | | Precipitation Rate (g/dm²/h) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Moving Average Intervals | | |
| | | | | | | | | 6 min | 20 min | 35 min |
| YUL | 14/12/1995 | 21:16 | -11.8 | S- | 40 | 40.00 | | ( a ) | ( b ) | ( c ) |
| YUL | 14/12/1995 | 21:17 | -11.7 | S- | 40 | 40.16 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:18 | -11.6 | S- | 40 | 40.31 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:19 | -11.6 | S- | 40 | 40.47 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:20 | -11.6 | S- | 40 | 40.63 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:21 | -11.6 | S- | 40 | 40.78 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:22 | -11.6 | S- | 40 | 40.94 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:22 | -11.5 | S- | 40 | 41.09 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:23 | -11.6 | S- | 40 | 41.25 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:24 | -11.6 | S- | 40 | 41.41 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:24 | -11.4 | S- | 40 | 41.56 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:25 | -11.4 | S- | 40 | 41.72 | | [illegible] | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:25 | -11.5 | S- | 40 | 41.88 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:26 | -11.5 | S- | 40 | 42.03 | | 9.38 | 9.79 | 13.16 |
| YUL | 14/12/1995 | 21:26 | -11.4 | S- | 40 | 42.19 | | 9.38 | 10.20 | 13.39 |
| YUL | 14/12/1995 | 21:27 | -11.4 | S- | 40 | 42.34 | | 9.38 | 10.62 | 13.48 |
| YUL | 14/12/1995 | 21:28 | -11.4 | S- | 40 | 42.50 | | 9.38 | 11.03 | 13.57 |
| YUL | 14/12/1995 | 21:29 | -11.4 | S- | 40 | 42.66 | | 9.38 | [illegible] | 13.66 |
| YUL | 14/12/1995 | 21:30 | -11.4 | S- | 40 | 42.81 | | 9.38 | [illegible] | 13.75 |
| YUL | 14/12/1995 | 21:31 | -11.4 | S- | 40 | 42.97 | | [illegible] | 12.27 | 13.84 |
| YUL | 14/12/1995 | 21:31 | -11.3 | S- | 40 | 43.13 | | 9.38 | 12.68 | 13.93 |
| YUL | 14/12/1995 | 21:32 | -11.3 | S- | 40 | 43.28 | | 9.38 | 13.10 | 14.02 |
| YUL | 14/12/1995 | 21:32 | -11.4 | S- | 40 | 43.44 | | 9.38 | 13.51 | 14.11 |
| YUL | 14/12/1995 | 21:33 | -11.4 | S- | 40 | 43.59 | | 9.38 | 13.92 | 14.20 |
| YUL | 14/12/1995 | 21:33 | -11.3 | S- | 40 | 43.75 | | 9.38 | 14.34 | 14.29 |
| YUL | 14/12/1995 | 21:34 | -11.3 | S- | 40 | 43.91 | | 9.38 | 14.75 | 14.38 |
| YUL | 14/12/1995 | 21:34 | -11.3 | S- | 40 | 44.06 | | 9.38 | 15.17 | 14.46 |
| YUL | 14/12/1995 | 21:35 | -11.3 | S- | 40 | 44.22 | | 10.75 | 15.58 | 14.55 |
| YUL | 14/12/1995 | 21:35 | -11.2 | S- | 40 | 44.38 | | 12.13 | 15.99 | 14.64 |
| YUL | 14/12/1995 | 21:36 | -11.2 | S- | 40 | 44.53 | | 13.51 | 16.41 | 14.73 |
| YUL | 14/12/1995 | 21:36 | -11.2 | S- | 40 | 44.69 | | 14.89 | 16.56 | 14.82 |
| YUL | 14/12/1995 | 21:37 | -11.2 | S- | 40 | 44.84 | | 16.27 | 16.72 | 14.91 |
| YUL | 14/12/1995 | 21:37 | -11.2 | S- | 45 | 45.00 | | 17.65 | 16.88 | 15.00 |
| YUL | 14/12/1995 | 21:38 | -11.2 | S- | 45 | 45.29 | | 17.65 | 16.62 | 14.85 |
| YUL | 14/12/1995 | 21:39 | -11.2 | S- | 45 | 45.59 | | 17.65 | 16.36 | 14.71 |
| YUL | 14/12/1995 | 21:40 | -11.2 | S- | 45 | 45.88 | | 17.65 | 16.10 | 14.56 |
| YUL | 14/12/1995 | 21:41 | -11.1 | S- | 45 | 46.18 | | 17.65 | 15.85 | 14.41 |
| YUL | 14/12/1995 | 21:42 | -11.1 | S- | 45 | 46.47 | | 17.65 | 15.59 | 14.26 |
| YUL | 14/12/1995 | 21:43 | -11.1 | S- | 45 | 46.76 | | 17.65 | 15.33 | 14.12 |
| YUL | 14/12/1995 | 21:44 | -11.1 | S- | 45 | 47.06 | | 17.65 | 15.07 | 14.18 |
| YUL | 14/12/1995 | 21:45 | -11.1 | S- | 45 | 47.35 | | 17.65 | 14.82 | 14.25 |
| YUL | 14/12/1995 | 21:46 | -11.1 | S- | 45 | 47.65 | | 17.65 | 14.56 | 14.32 |
| YUL | 14/12/1995 | 21:47 | -11.1 | S- | 45 | 47.94 | | 17.65 | 14.30 | 14.39 |
| YUL | 14/12/1995 | 21:47 | -11.0 | S- | 45 | 48.24 | | 17.65 | 14.04 | 14.45 |
| YUL | 14/12/1995 | 21:48 | -11.0 | S- | 45 | 48.53 | | 16.79 | 13.79 | 14.52 |
| YUL | 14/12/1995 | 21:49 | -11.0 | S- | 45 | 48.82 | | 15.93 | 13.53 | 14.59 |
| YUL | 14/12/1995 | 21:50 | -11.0 | S- | 45 | 49.12 | | 15.07 | 13.27 | 14.66 |
| YUL | 14/12/1995 | 21:51 | -11.0 | S- | 45 | 49.41 | | 14.22 | 13.01 | 14.72 |
| YUL | 14/12/1995 | 21:52 | -10.9 | S- | 45 | 49.71 | | 13.36 | 12.76 | 14.79 |
| YUL | 14/12/1995 | 21:53 | -10.8 | S- | 50 | 50.00 | | 12.50 | 12.50 | 14.86 |

( a ) = (40.94 - 40.00)*60 / 6
( b ) = (43.13 - 40.00)*60 / 20
( a ) = (45.88 - 40.00)*60 / 35

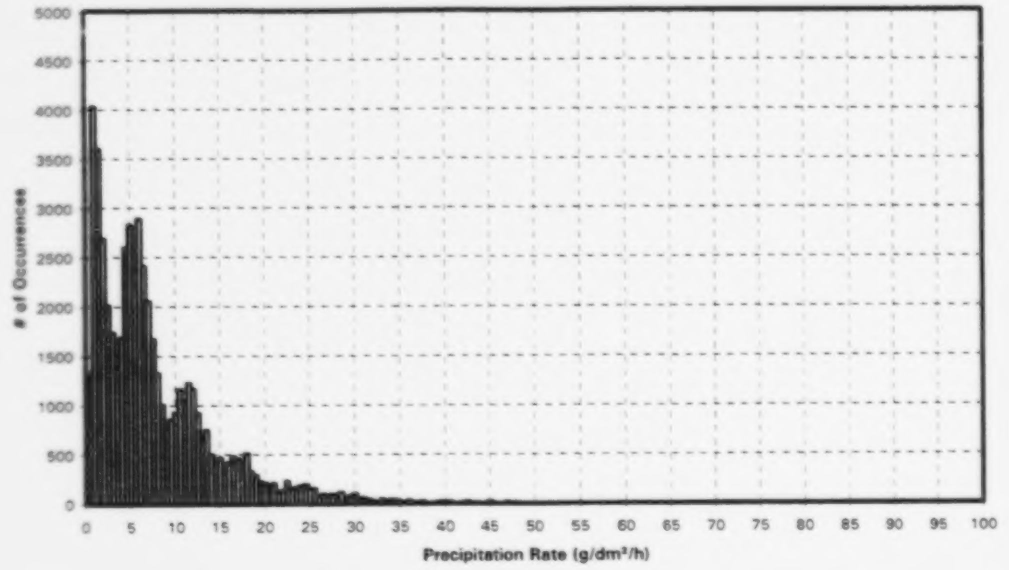

Figure 4.1: READAC and CR21X Analysis – Natural Snow Histogram

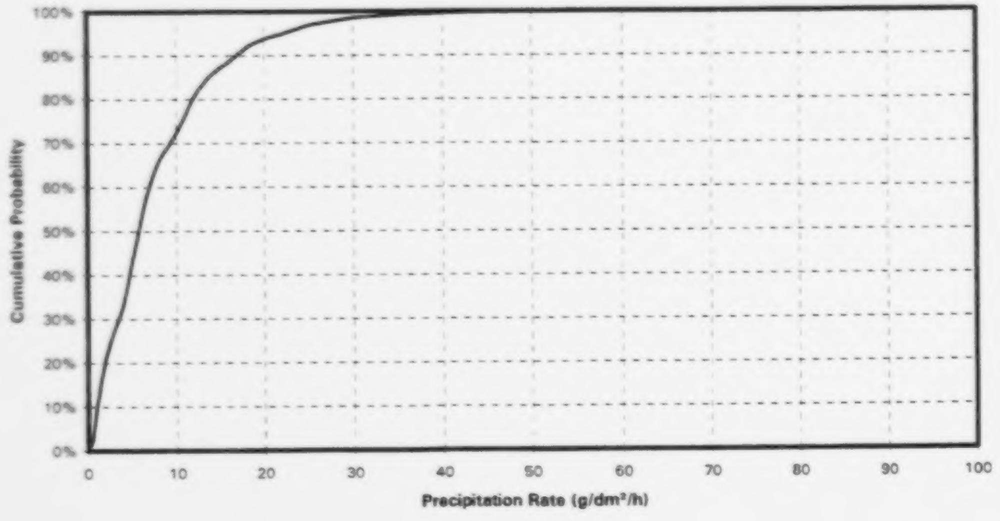

Figure 4.2: READAC and CR21X Analysis – Natural Snow Chart

Figure 4.3 shows a comparison of precipitation rates of the READAC gauge and the plate pans for a storm on 15 January 1999. Figure 4.4 illustrates another comparison, this time for the CR21X gauge during the storm on 15 January 1999. These charts were extracted from Transport Canada report TP 13486E, *Evaluation of Snow Weather Data for Aircraft Anti-Icing Holdover Times* (10).

Figures 4.3 and 4.4 show the precipitation rate for a 24-hour period. The 6-minute moving average rates calculated from the CR21X data show much more detail. Higher rates were detected from this station; perhaps this is due to the fact that the smoothed data from the lower resolution READAC station does not allow for the detection of rapid increases and decreases in rates.

Plate pan data collected from the APS test site located at Dorval Airport are included in Figures 4.3 and 4.4. The pans were placed at a 10° angle on test stands approximately 30 m away from the precipitation gauge. The rates from the pans are based on the weight of snow that collected in the pans during a 10-minute period. The rates were recorded at the end of this time interval. Both the upper and lower rate pans are included in the figures.

In addition, because of questions raised by MSC concerning the accuracy of precipitation gauges, a new analysis was conducted on the winter 2000-01 data. Following the same methodology, the CR21X gauge data was plotted against the plate pan data, collected by APS at Dorval on 11 January 2001. The results are presented in Figure 4.5.

As shown, the data points from the plate pans correlate well with the traces shown in Figures 4.3, 4.4 and 4.5. More precipitation collects in the rate pans during high winds because the stands are always placed facing the wind. The differences between the precipitation gauge trace and the plate pan points could be due to the 10° angle of the test stand.

Even so, CR21X and READAC results are close to the plate pan collection results, and therefore could be used to analyze precipitation data.

At least one verification should be made annually by comparing the rates obtained from the precipitation gauges and the plate pans.

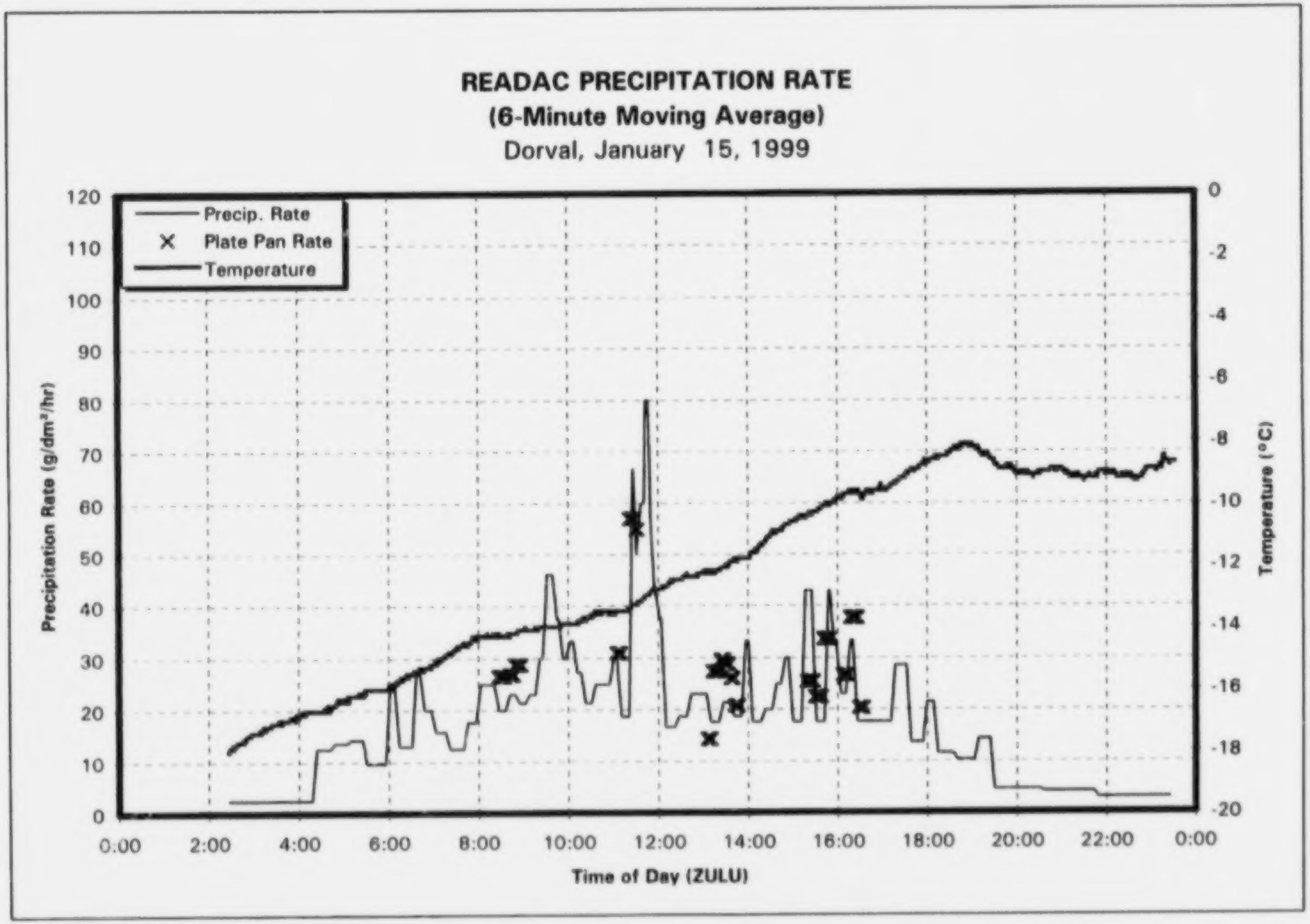

Figure 4.3: READAC Precipitation Rate, 15 January 1999

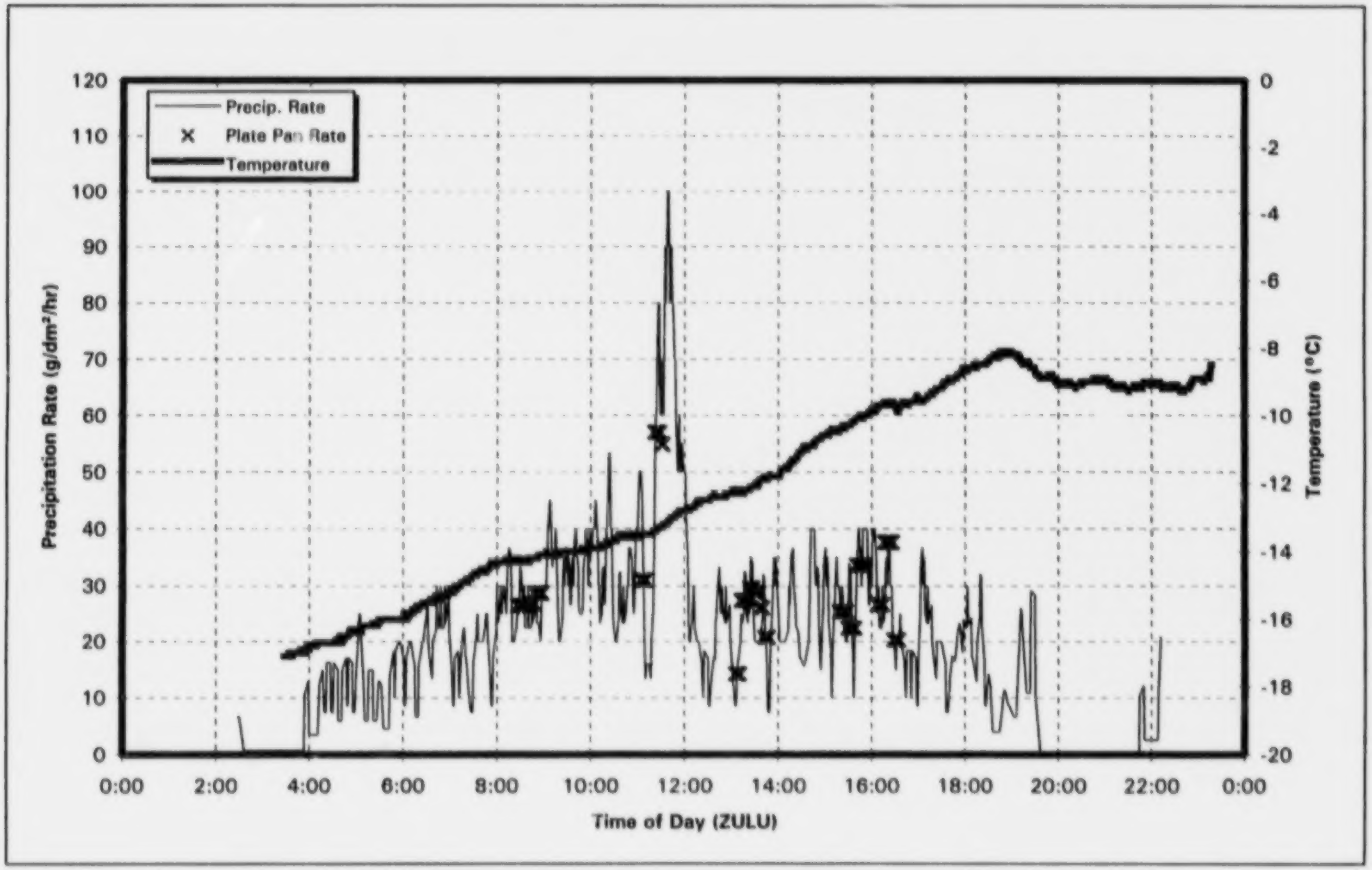

Figure 4.4: CR21X Precipitation Rate, 15 January 1999

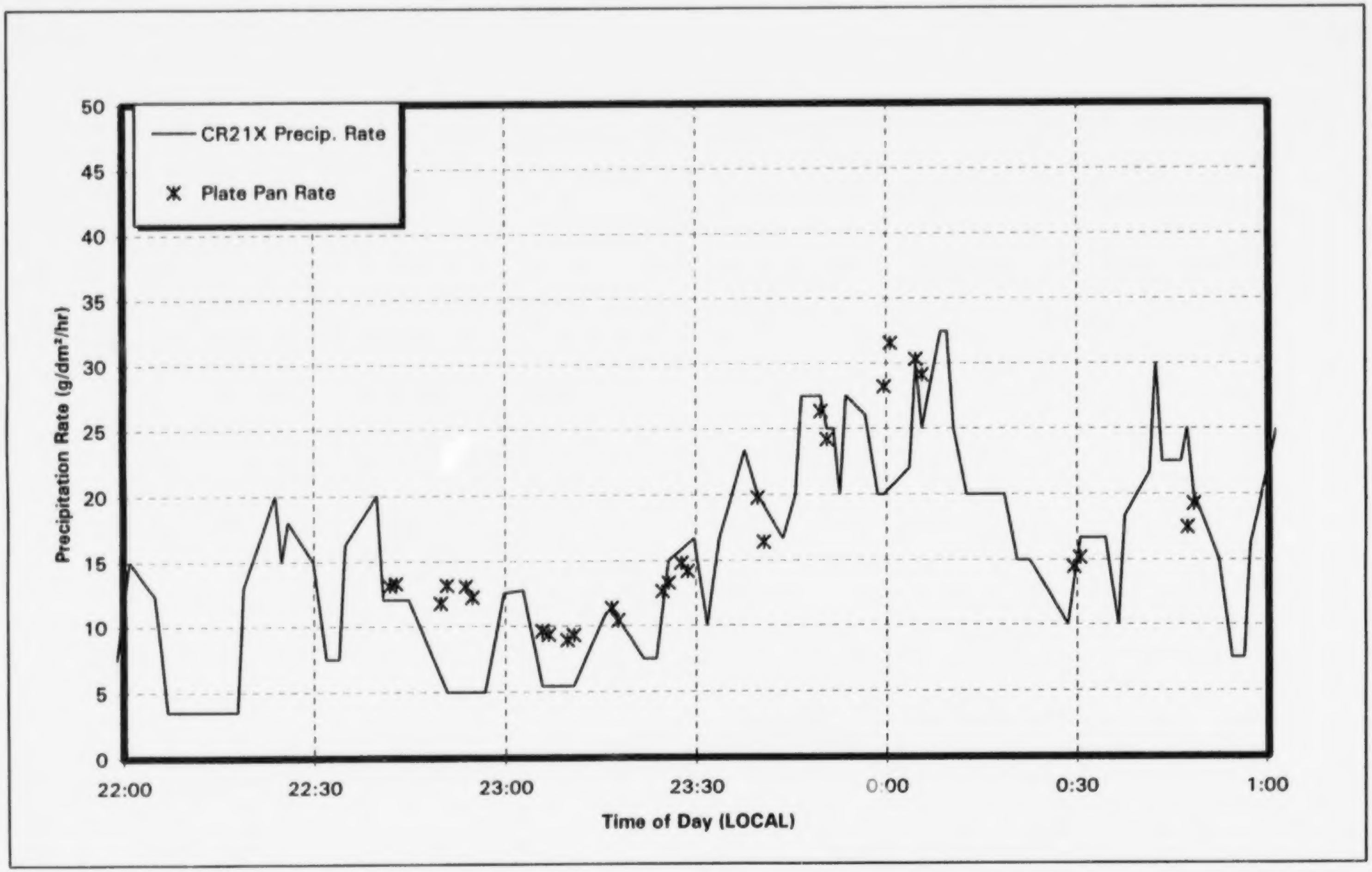

Figure 4.5: CR21X Precipitation Rate, 11 January 2001

## 4.2 Natural Snow

The 95th percentiles for several temperature ranges for natural snow conditions are shown in Table 4.2.

**Table 4.2: 95th Percentile in Each Temperature Range – Natural Snow**

| Temperature Range | 95th Percentile Precipitation Rate (g/dm²/h) | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| Above 0°C | 20 | 19 | 19 |
| 0°C to -3°C | 20 | 19 | 19 |
| -3°C to -7°C | 22 | 22 | 22 |
| -7°C to -14°C | 22 | 22 | 22 |
| -14°C to -25°C | 22 | 21 | 21 |

Each of the rates in this table represents the one below which 95 percent of all snowfalls occurred in a specific temperature range for a given rate duration. For example, in the temperature range of -3°C to -7°C and for a duration of 20 minutes, the 95th percentile is 22 g/dm$^2$/h. This indicates that 95 percent of the 20-minute rates recorded between -3°C to -7°C were equal to or below 22 g/dm$^2$/h. The percent of occurrences when the precipitation rates were above 25 g/dm$^2$/h are shown in Table 4.3 for all temperature ranges.

**Table 4.3: Percentage of Heavy Snow Occurrences in Each Temperature Range Natural Snow**

| Temperature Range | Percent of Occurrences when Rate is above 25 g/dm²/h | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| Above 0°C | 2.4% | 2.5% | 2.2% |
| 0°C to -3°C | 2.5% | 2.3% | 2.0% |
| -3°C to -7°C | 3.4% | 3.2% | 3.0% |
| -7°C to -14°C | 3.3% | 3.4% | 3.4% |
| -14°C to -25°C | 2.7% | 2.5% | 2.9% |

## 4.3 Snow at Cold Temperatures

The general shape of the cumulative probability of occurrence curves at colder temperatures is similar to that of the curves drawn at other temperatures, as shown in Figure 4.6. The -7°C to -14°C temperature interval represents the highest 95th percentile precipitation rate. This indicates that high rates do occur at cold temperatures.

The coldest temperature interval was divided into three smaller intervals (data shown in Appendix B):

- -14°C to -18°C
- -18°C to -22°C
- -22°C to -25°C

High precipitation rates were more common in the -14°C to -18°C range, but few high rate snowfalls were recorded in the other two ranges, as shown in Figure 4.7. It should be noted, however, that the 95th percentile was above 17 $g/dm^2/h$ for all subdivided intervals. The percentage of occurrences when the precipitation rates were above 25 $g/dm^2/h$ is shown in Table 4.4 for the subdivided intervals.

**Table 4.4: Percentage of Heavy Snow Occurrences in Cold Temperatures – Natural Snow**

| Temperature Range | Percent of Occurrences when Rate is above 25 $g/dm^2/h$ | | | Percent of -14 to -25°C Data Points in Each Temperature Range | Percent of Total Data Points in Each Temperature Range |
|---|---|---|---|---|---|
| | 6 min | 20 min | 35 min | | |
| -14 to -18°C | 3.6% | 3.5% | 4.0% | 70.0% | 4.4% |
| -18 to -22°C | 0.4% | 0% | 0% | 24.0% | 1.5% |
| -22 to -25°C | 1.2% | 0.6% | 0% | 6.0% | 0.4% |
| | | | Total | 100% | 6.3% |

Based on these results, consideration should be given to reformatting the holdover time tables by dividing the -14°C to -25°C interval, because precipitation rates were significantly lower at temperatures below -18°C and occurrences were less frequent.

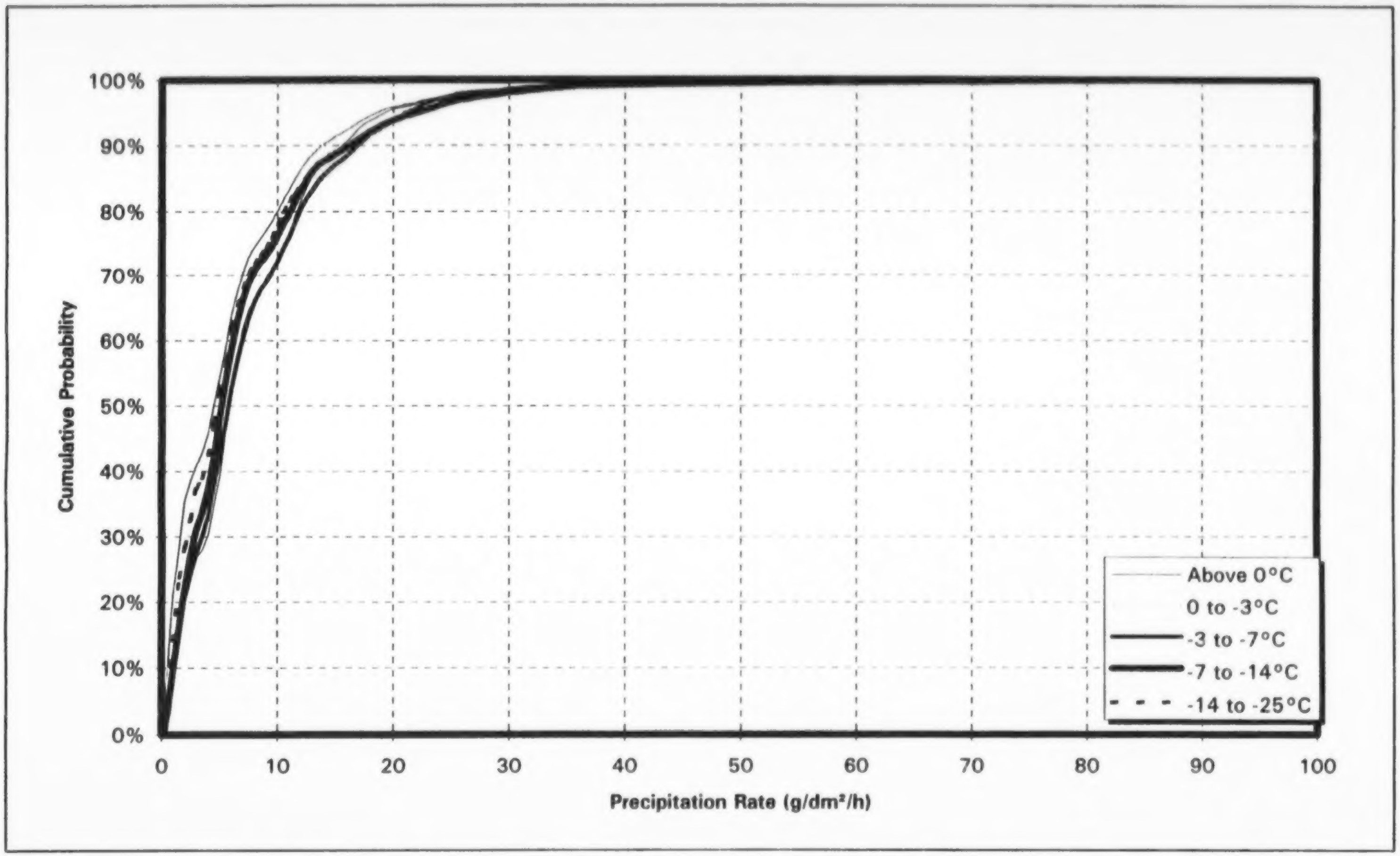

Figure 4.6: 20-Minute Rate Every Minute for All Temperature Ranges

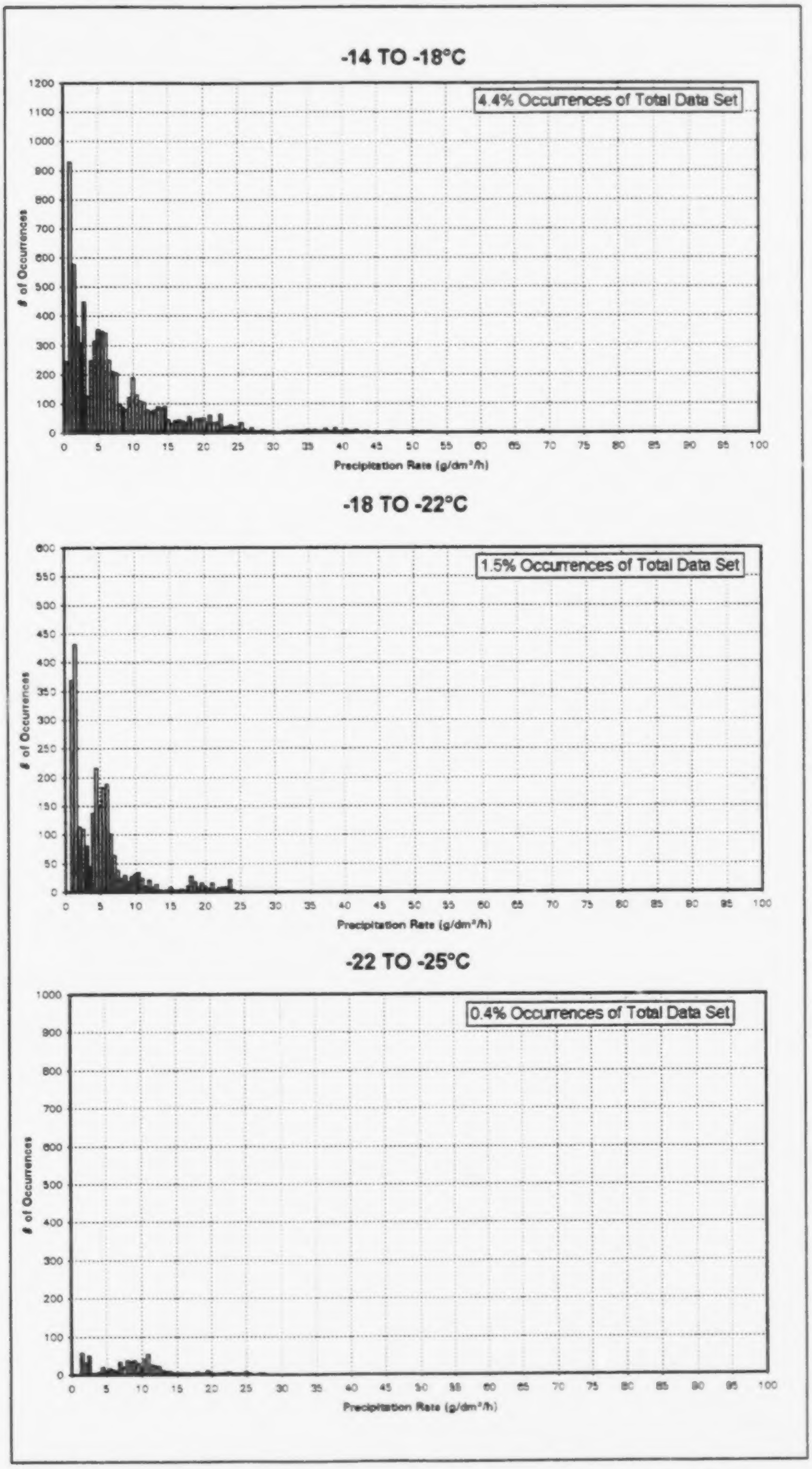

Figure 4.7: Subdivision of -14°C to -25°C Snow Data

## 4.4 Comparing MSC with APS 1995 to 2001 Snow Weather Data

A study of the precipitation rate in each holdover time temperature interval was prepared in 1995 by MSC. This study, based on data collected at an experimental site at Pearson Airport, is included in Appendix D. The graphs (Cumulative Probability versus Precipitation Rate) were reasonably similar in overall curve shape but not necessarily in exact values. For the temperature range of 0°C to -3°C, the results of the MSC study are very similar to those in this report. The 6-, 20-, and 35-minute rates are nearly identical in both studies. The 95th percentile was 16 $g/dm^2/h$ in the MSC report and 19 $g/dm^2/h$ in this one.

In the -3°C to -7°C temperature range, the general shape of the curves is not as similar as the 0°C to -3°C curves. The findings of this study show that only 70 percent of precipitation is expected to be below 10 $g/dm^2/h$. The findings of the MSC study suggest that 87 percent of precipitation will be at a rate lower than 10 $g/dm^2/h$. The curves from the APS and the MSC studies show very little change in precipitation rate for the various time intervals, although a slight tendency toward higher rates is shown for shorter time intervals in the MSC study.

The 95th percentile rates, based on data collected from the READAC and CR21X stations, are 22 $g/dm^2/h$ for the -7°C to -14°C range. The 95th percentile precipitation rates for this temperature range are significantly higher than those of the MSC study primarily due to very high rates recorded during at least two specific snowfalls during the 1998-99 winter.

The -14°C to -25°C range presents the largest variation in results between the two studies. The MSC graphs indicate that snow precipitation rates in that temperature range are much lower than in the other ranges. The MSC study shows that 98 percent of the precipitation is expected to be below 10 $g/dm^2/h$ (only 72 percent according to APS study). These findings do not match the results of this report. The data from the READAC and CR21X stations show very little difference in the probability versus precipitation rate curves for various temperature ranges.

Overall, these two data sets (MSC and APS) are similar enough to compare with each other for temperature ranges above -7°C. Below that temperature, the MSC data contain no high rate precipitation points. The data collected by MSC were recorded in Toronto. The average temperature is warmer in that region than in the regions where the APS data were collected. This resulted in colder ambient temperatures in the data analyzed for this study.

## 4.5 Comparison of APS 1993 to 1995 with 1995 to 2001 Snow Weather Data

Preliminary analysis of these two sets of data revealed that numerous data conversions are needed to help make substantial conclusions. Variations in scales between the two data sets can present other difficulties. The data presented in the 1993 to 1995 analysis were not separated into temperature ranges. The 95th percentiles, shown in Table 4.5, were approximated from the graphs presented in Appendix C.

**Table 4.5: Summary of 1993 to 1995 Snow Weather Data**

| Date | Ambient Temperature (°C) | 95th Percentile Snowfall Rate ($g/dm^2/h$) |
|---|---|---|
| 1993/1995 | N/A | 26 |
| 1993/1994 | N/A | 37 |
| 21-Dec-93 | 0.5 | 37 |
| 1-Apr-94 | -13 | 61 |
| 8-Jan-94 | -18 | 11 |
| 14-Jan-94 | -10 | 5 |
| 23-Jan-94 | -16 | 13 |
| 27-Jan-94 | -9 | 27 |
| 12-Feb-94 | -8 | 17 |
| 23-Feb-94 | -9 | 31 |
| 10-Mar-94 | -5 | 19 |
| 27-Mar-94 | 0.2 | 31 |
| 7-Apr-94 | -1.3 | 16 |
| 1994/1995 | N/A | 21 |
| 7-Jan-95 | -3 | 17 |
| 12-Jan-95 | -14 | 20 |
| 4-Feb-95 | -8 | 9 |
| 11-Feb-95 | -9 | 14 |
| 16-Feb-95 | -1 | 28 |
| 24-Feb-95 | -0.2 | 11 |
| 27-Feb-95 | -12 | 13 |
| 6-Mar-95 | -7 | 25 |
| 8-Mar-95 | -5 | 17 |

From these data it can be observed that very high snowfall rates were recorded during the 1993-1994 winter. The 95th percentile for the entire temperature range from 1993 to 1995 was 21 g/dm$^2$/h.

## 4.6 Freezing Rain / Drizzle

The 95th percentile for two temperature ranges is shown in Table 4.6 for freezing rain/drizzle.

**Table 4.6: 95th Percentile in Each Temperature Range – Freezing Rain/Drizzle**

| Temperature Range | 95th Percentile Precipitation Rate (g/dm$^2$/h) | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| 0°C to -3°C | 30 | 26 | 24 |
| -3°C to -10°C | 25 | 25 | 24 |

In freezing rain/drizzle, the 95th percentile was near 24 g/dm$^2$/h for the -3°C to -10°C range and slightly higher, near 26 g/dm$^2$/h, for the 0°C to -3°C range.

## 4.7 Relation between Weather Data and SAE Holdover Time Tables

The probability of snow event occurrences in each of the holdover time temperature ranges of the Holdover Time tables is shown in Tables 4.7 and 4.8. Table 4.7 corresponds to the temperature ranges of Type I fluid and Table 4.8 to the ranges of Type II and Type IV fluids. There were no data available for natural snow conditions below -25°C. In addition, each of the tables provides probability data for snowfall as a function of light, moderate, and heavy snow.

For Type I, over 72 percent of the probability of snow events occurred in the range of 0°C to -10°C. Over 71 percent of the rates were classified as light snow (<10 g/dm$^2$/hr). The probability of snow events for Type IV followed a similar pattern with 61 percent in the range of -3°C to -14°C and with over 74 percent of these rates classified as light snow.

**Table 4.7: Type I Probability of Snow Event in Each Holdover Time Cell**

| Temperature (°C) | Light Snow (< 10 g/dm²/h) | Moderate Snow (10 to 25 g/dm²/h) | Heavy Snow (> 25 g/dm²/h) | Total |
|---|---|---|---|---|
| Above 0°C | 6.5% | 2.8% | 0.3% | **9.5%** |
| 0 to -10°C | 52.7% | 17.7% | 2.1% | **72.5%** |
| Below -10°C | 12.7% | 4.5% | 0.7% | **18.0%** |
| **Total** | **71.9%** | **25.0%** | **3.1%** | **100.0%** |

**Table 4.8: Type II and Type IV Probability of Snow Event in Each Holdover Time Cell**

| Temperature (°C) | Light Snow (< 10 g/dm²/h) | Moderate Snow (10 to 25 g/dm²/h) | Heavy Snow (> 25 g/dm²/h) | Total |
|---|---|---|---|---|
| Above 0°C | 6.7% | 2.5% | 0.3% | **9.4%** |
| 0 to -3°C | 18.6% | 4.5% | 0.5% | **23.6%** |
| -3 to -14°C | 44.2% | 14.5% | 2.1% | **60.7%** |
| -14 to -25°C | 4.7% | 1.4% | 0.2% | **6.2%** |
| **Total** | **74.1%** | **22.8%** | **3.0%** | **100.0%** |

### 4.7.1 Number of Frost Deicings at Dorval

Data representing the number of aircraft deicing events performed at Dorval Airport were obtained for the 1995-96 winter. These were then separated into two categories: frost related deicing and precipitation-related deicing.

This classification was based on the airport deicing logs and the READAC station log. An example of the airport deicing log is shown in Table 4.9.

The chart shown in Figure 4.8 indicates that 1008 aircraft deicings were attributed to frost. This represents 20.4 percent of all deicings performed during the winter of 1995-96. Figure 4.9 separates the frost deicings into various temperature ranges. The largest number of deicings occurred between -15°C and -20°C.

### 4.7.2 Number of Deicings for All Conditions at Dorval

Additional data were obtained from deicing operations during the 1999-2000 winter season at Dorval. AéroMag 2000, deicers at Dorval, indicated that frost accounted for 31 percent of the deicing operations. Based on this value and Figure 4.8, an average of frost deicing operations at Dorval was calculated to be 25 percent. This implies that 75 percent of the deicing operations are for freezing precipitation. Using the summary of hourly weather observations (11) for over 30 years of data at Dorval, freezing drizzle, freezing rain, and freezing fog have been observed about 6 percent of the time that freezing precipitation is observed (i.e. when there is freezing precipitation, it falls as snow 94 percent of the time). By calculating these percentages out of the 75 percent of non-frost deicing, and after rounding the numbers, it was established that freezing precipitation is 5 percent of deicing of all conditions, and snow represents 70 percent.

Based on this information, the estimate of frequency of deicing operations at Dorval is shown on the pie chart in Figure 4.10.

Table 4.10 and Table 4.11, developed using the Dorval log, show the distribution of deicing operations. As observed above, 95 percent of operations are for snow and frost removal, and only 5 percent are for freezing fog/rain/drizzle and rain on cold soaked wings.

## Table 4.9: Extract of Dorval Airport Deicing Log

DORVAL AIRPORT
DEICING LOG: 1995-1996 WINTER

| DATE | TIME | DEICING COMPANY | AIRLINE COMPANY | FLIGHT # | SITE | FLUID TYPE | FLUID QUANTITY (L) | CONC. |
|---|---|---|---|---|---|---|---|---|
| 9/29/1995 | 6:50 | AIR CANADA | AIR CANADA | 117 | E | 1 | 136.38 | 54% |
| 9/29/1995 | 7:15 | AIR CANADA | AIR CANADA | 781 | E | 1 | 90.92 | 54% |
| 9/29/1995 | 7:37 | AIR CANADA | AIR CANADA | 433 | E | 1 | 90.92 | 54% |
| 10/30/1995 | 17:00 | CANADIEN | CANADIEN | 108 | S | 1 | 25.00 | 54% |
| 10/31/1995 | 6:45 | AIR CANADA | AIR CANADA | 117 | E | 1 | 345.49 | 30% |
| 10/31/1995 | 6:45 | AIR CANADA | AIR ONTARIO | 371 | E | 1 | 72.73 | 30% |
| 10/31/1995 | 6:50 | AIR CANADA | AIR CANADA | 825 | E | 1 | 154.56 | 30% |
| 10/31/1995 | 6:55 | AIR CANADA | AIR CANADA | 781 | E | 1 | 118.19 | 30% |
| 10/31/1995 | 7:00 | AIR CANADA | AIR CANADA | 770 | E | 1 | 90.92 | 30% |
| 10/31/1995 | 7:00 | AIR CANADA | AIR CANADA | 401 | E | 1 | 322.76 | 30% |
| 10/31/1995 | 7:00 | CANADIEN | CANADIEN | 961 | S | 1 | 15.00 | 54% |
| 10/31/1995 | 7:05 | AIR CANADA | AIR CANADA | 740 | E | 1 | 104.56 | 30% |
| 10/31/1995 | 7:30 | AIR CANADA | AIR CANADA | 433 | E | 1 | 150.01 | 30% |
| 10/31/1995 | 7:59 | DELTA | DELTA | 611 | W | 1 | 94.64 | 54% |
| 10/31/1995 | 8:00 | AIR CANADA | AIR CANADA | 403 | E | 1 | 331.85 | 30% |
| 10/31/1995 | 8:00 | AIR CANADA | AIR CANADA | 928 | E | 1 | 131.83 | 30% |
| 10/31/1995 | 8:00 | NORTHWEST | NORTHWEST | 1254 | W | 1 | 113.65 | 54% |
| 10/31/1995 | 8:29 | DELTA | DELTA | 2089 | W | 1 | 94.64 | 54% |
| 10/31/1995 | 8:55 | AIR CANADA | AIR CANADA | 920 | E | 1 | 140.92 | 30% |
| 11/1/1995 | 16:00 | AIR CANADA | AIR CANADA | 787 | E | 1 | 104.56 | 30% |
| 11/1/1995 | 16:00 | AIR CANADA | AIR CANADA | 787 | E | 1 | 104.56 | 30% |
| 11/1/1995 | 17:00 | AIR CANADA | AIR CANADA | 139 | E | 1 | 163.65 | 30% |
| 11/1/1995 | 17:00 | AIR CANADA | AIR CANADA | 139 | E | 1 | 163.65 | 30% |
| 11/1/1995 | 17:30 | AIR CANADA | AIR CANADA | 135 | E | 1 | 213.66 | 30% |
| 11/1/1995 | 17:30 | AIR CANADA | AIR CANADA | 175 | E | 1 | 140.92 | 30% |
| 11/1/1995 | 17:30 | AIR CANADA | AIR CANADA | 135 | E | 1 | 213.66 | 30% |
| 11/1/1995 | 17:30 | AIR CANADA | AIR CANADA | 175 | E | 1 | 140.92 | 30% |
| 11/1/1995 | 18:00 | AIR CANADA | AIR CANADA | 423 | E | 1 | 390.95 | 30% |
| 11/1/1995 | 18:00 | AIR CANADA | AIR CANADA | 155 | E | 1 | 154.56 | 30% |
| 11/1/1995 | 18:00 | AIR CANADA | AIR CANADA | 155 | E | 1 | 154.56 | 30% |
| 11/1/1995 | 18:00 | AIR CANADA | AIR CANADA | 423 | E | 1 | 390.95 | 30% |
| 11/1/1995 | 18:05 | DELTA | DELTA | 637 | N | 1 | 189.27 | 54% |
| 11/1/1995 | 18:10 | AIR CANADA | AIR CANADA | 144 | E | 1 | 159.11 | 30% |
| 11/1/1995 | 18:10 | AIR CANADA | AIR CANADA | 144 | E | 1 | 159.11 | 30% |
| 11/1/1995 | 18:15 | AIR CANADA | AIR CANADA | 572 | E | 1 | 122.74 | 30% |

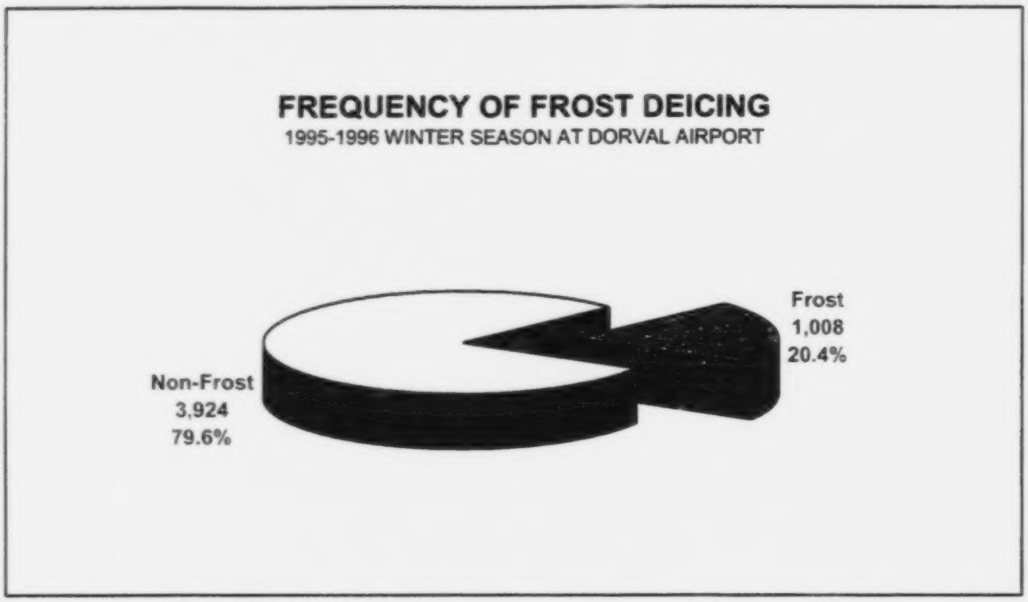

Figure 4.8: Frequency of Frost Deicing

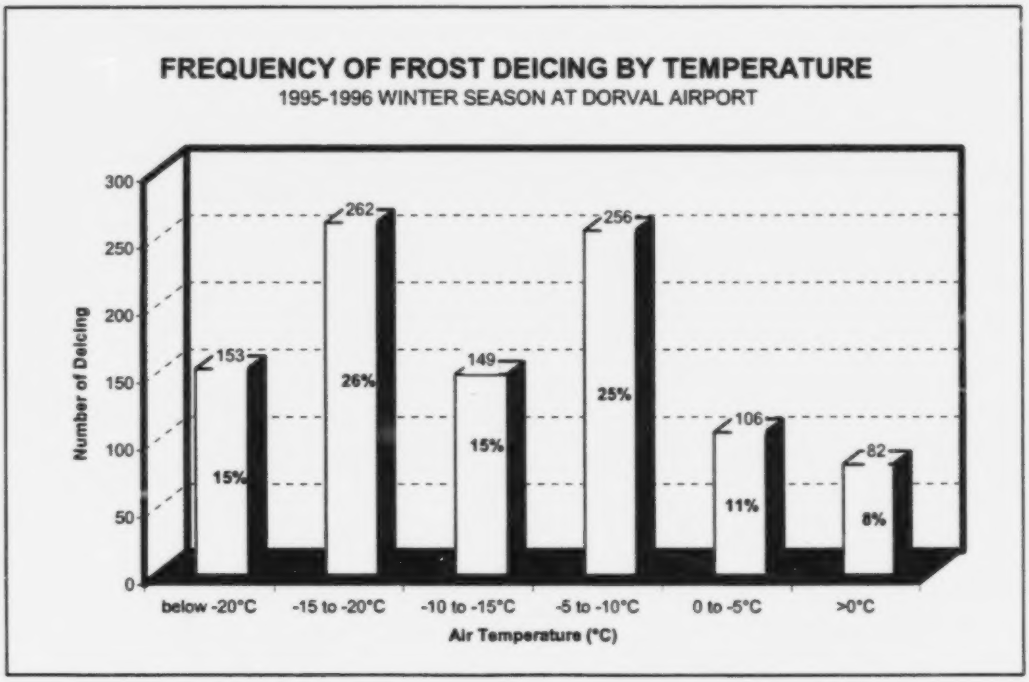

Figure 4.9: Frequency of Frost Deicing by Temperature

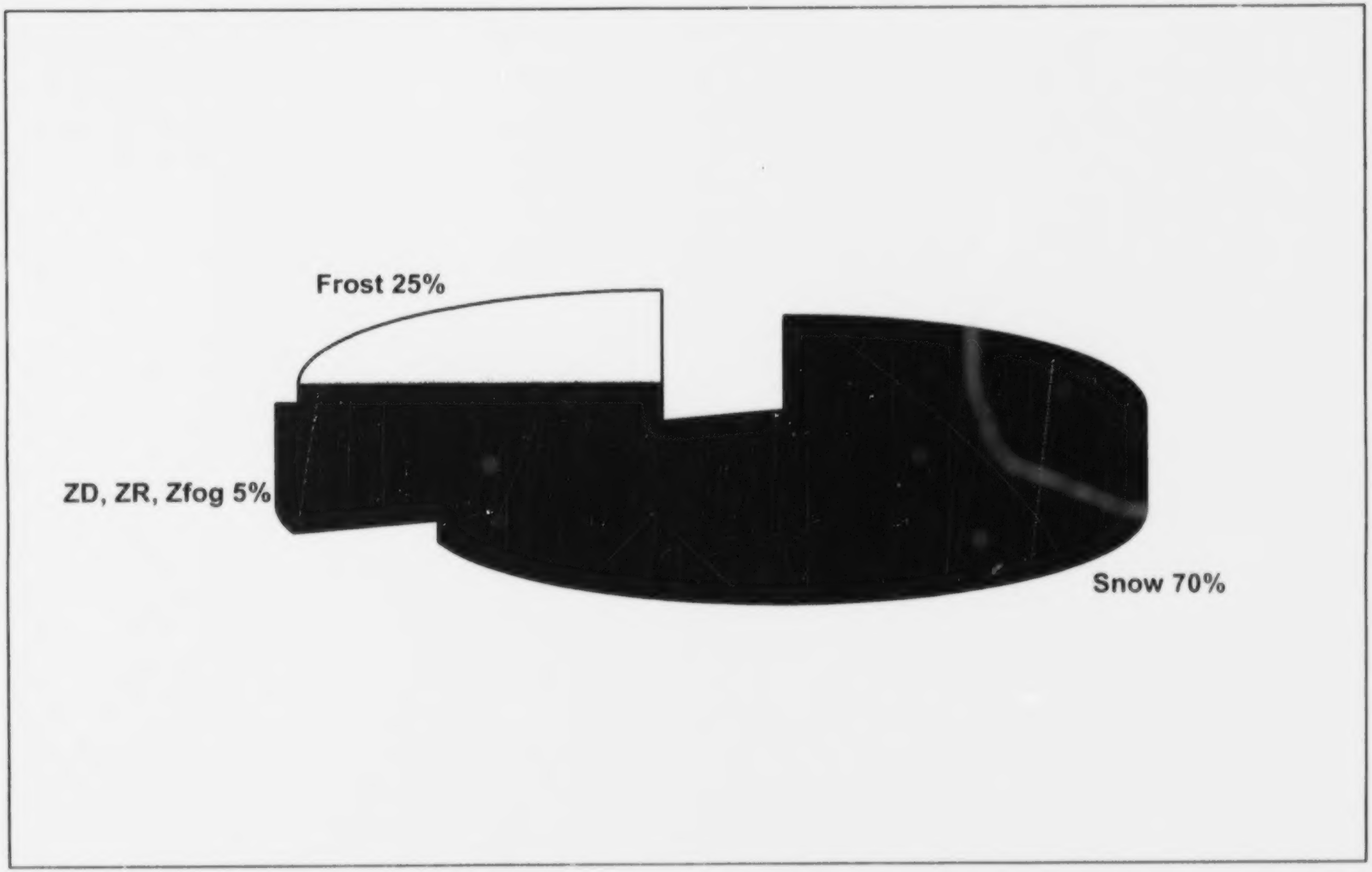

Figure 4.10: Estimate of Frequency of Deicing Operations at Dorval

## Table 4.10: Distribution of Deicing Operations in Montreal for Type I Fluids

**All values are estimates:** ☒

| OAT | | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| °C | °F | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | 2.0% | 0.0% | 6.8% | 0.2% | 0.4% | 1.0% | | 10.4% |
| 0 to -10 | 32 to 14 | 9.0% | 0.5% | 51.0% | 0.8% | 1.6% | | | 62.9% |
| below -10 | below 14 | 14.0% | 0.5% | 12.2% | | | | | 26.7% |
| | Total | 25.0% | 1.0% | 70.0% | 1.0% | 2.0% | 1.0% | | |

**100% of Operations**

## Table 4.11: Distribution of Deicing Operations in Montreal for Type IV and II Fluids

Total # of Deicing Operations: 5000 Type I Included ☒ All values are estimates: ☒

| OAT | | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| °C | °F | | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | 100/0 | 2.0% | 0.0% | 6.6% | 0.2% | 0.4% | 1.0% | | 10.2% |
| | | 75/25 | | | | | | | | |
| | | 50/50 | | | | | | | | |
| 0 to -3 | 32 to 27 | 100/0 | 3.0% | 0.5% | 16.5% | 0.3% | 0.6% | | | 20.9% |
| | | 75/25 | | | | | | | | |
| | | 50/50 | | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 10.0% | 0.3% | 42.5% | 0.5% | 1.0% | | | 54.3% |
| | | 75/25 | | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 10.0% | 0.3% | 4.4% | | | | | 14.7% |
| below -25 | below -13 | 100/0 | 0.0% | 0.0% | 0.0% | | | | | 0.0% |
| | | **Total** | 25.0% | 1.0% | 70.0% | 1.0% | 2.0% | 1.0% | | 100% of Operations |

To substantiate these findings and to have a better understanding of how consistent these results are at other worldwide stations, Transport Canada has initiated a survey (Appendix G) of several international airports. Tables concerning the percent of de/anti-icing operations at Dorval have been updated since the survey was distributed; therefore, the tables are not identical to those released to the airports.

## 4.8 Potential Changes to the Holdover Time Table Format

As described in Section 4.7, the majority of deicing operations at Dorval occur as a result of frost and snow. Most of the deicing operations are concentrated at the warmer temperatures, at or just below 0°C.

This section examines the suitability of the actual HOT table format by providing potential suggestions to changes in the temperature breakdown and also changes to the precipitation conditions.

The data analyzed in this report have shown that the most important winter weather condition encountered, in terms of de/anti-icing at Dorval, is snow (approximately 70 percent). This value of 70 percent for snow will be evaluated further, using the data that will be received from the survey of worldwide airlines (Appendix G). The importance and significance of the survey is to better evaluate and determine where to place the resources and funding of de/anti-icing research.

Some of the reasons as to why there is a need to consider changes to the HOT tables are described in the following subsections.

### 4.8.1 Type I Fluid HOT Table Situation

APS is currently evaluating the Type I fluid holdover time ranges for snow; more specifically the correctness of the existing values (6 to 15 minutes). The entire study can be found in Transport Canada report TP 13826E (2).

The existing SAE guidelines are presented for only three ranges of outside air temperature (OAT): above 0°C, 0°C to -10°C, and below -10°C. A conclusion from this report is that the current large temperature range from 0°C to -10°C incurs significant penalties on operations by bringing about shorter holdover times. This is illustrated in Figure 4.11 and Figure 4.12. A range that has -3°C as its lower limit will benefit from much longer times than one with -10°C as a lower limit. The HOT would increase from just under 6 minutes to about 14 minutes.

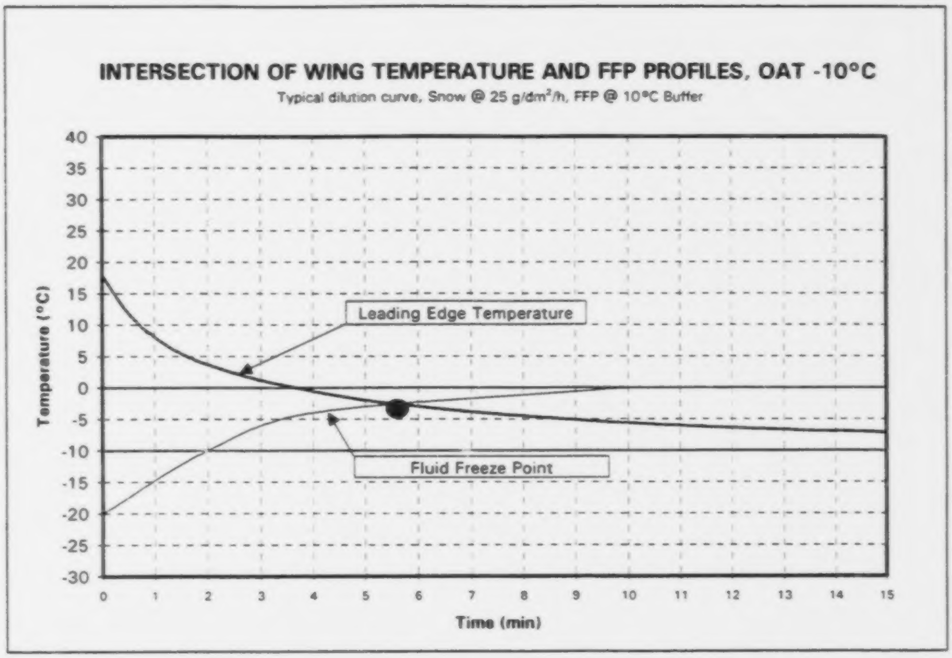

Figure 4.11: Intersection of Wing Temperature and FFP Profiles, OAT -10°C

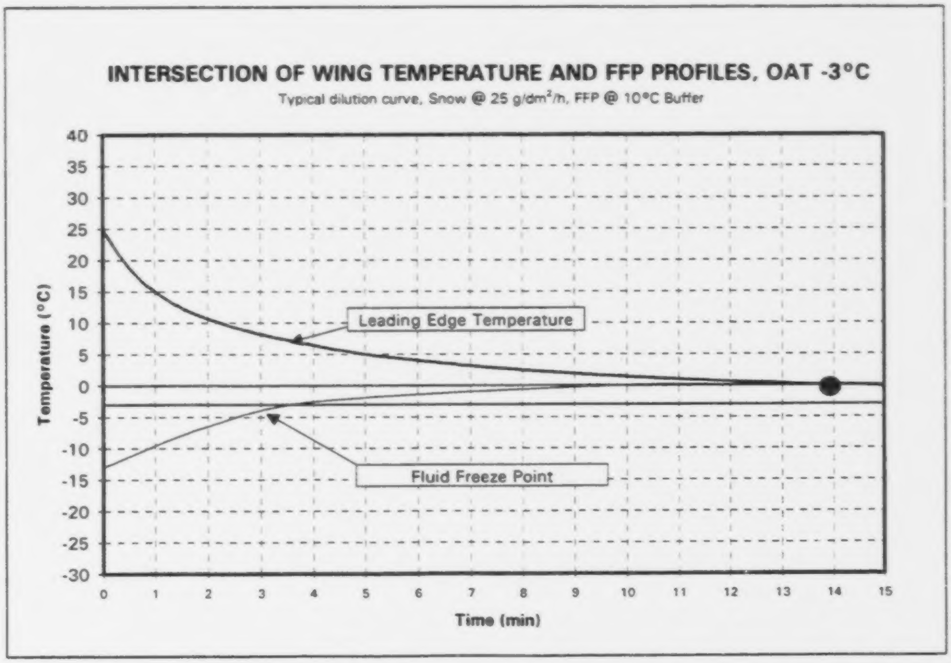

Figure 4.12: Intersection of Wing Temperature and FFP Profiles, OAT -3°C

As well, data on snowfall distribution indicates that the current large range from 0°C to -10°C could encompass up to 70 percent of all snowfall events. A finer split would better represent actual snowfall distribution by temperature.

### 4.8.2 Evaluation of the Type II/IV HOT Table Temperature Breakdowns

Figure 3.2 shows that over 60 percent of the snow precipitation was recorded between 0°C and -7°C, and over 80 percent between 0°C and -10°C. Currently, using the actual format of the Type II/IV HOT tables, any anti-icing operation done at a temperature below -3°C, but close to -3°C, would have to be considered as if it was done at -14°C. The HOT used is governed by the HOT at -14°C.

The example given below illustrates the impact of this using existing HOTs for a particular Type IV fluid.

Suppose that the:

- Temperature is: -2°C
- Precipitation condition is: snow
- Rate is: 24 g/dm$^2$/h (Moderate)
- Fluid Type is: Clariant MPIV 2001 100%

- ➢ Then the HOT guideline range for 0°C to -3°C is 1:00 to 1:55; and the HOT guideline a pilot would use is **1:00 hour** because the snow is moderate.
- ➢ However, if the temperature was -4°C rather than -2°C, then the HOT guideline range for -3°C to -14°C is 0:30 to 0:50; and the HOT guideline a pilot would use is **0:30 minutes**.
- ➢ The difference in time is **30 minutes** based on the current HOT chart for only a **2°C difference**. This situation occurs frequently, because the likelihood of snow between -3°C and, say -7°C, is high. This example clearly demonstrates that consideration should be given to changing the temperature ranges in the HOT tables.

When considering temperature break changes in the Type II/IV HOT Tables, thought needs to be given to the natural freeze point limits of the fluids and their dilutions to ensure that the required 7°C buffer is maintained.

### 4.8.3 Evaluation of Weather Conditions in HOT Tables

The precipitation rates for snow (10 g/dm$^2$/h and 25 g/dm$^2$/h) currently in use for the evaluation of upper and lower HOT limits were not modified. As they are now, the values in HOT table cells reflect the two rates.

Pilots typically use:

- The higher HOT value when the snow is light (0 g/dm$^2$/h to 10 g/dm$^2$/h).
- The lower HOT value when the snow is moderate (10 g/dm$^2$/h to 25 g/dm$^2$/h).

When the precipitation rate is higher than 25 g/dm$^2$/h, the caution note in the HOT tables indicates that there are no guidelines. However, pilots can easily misinterpret the HOT table values and incorrectly use the lower HOT during heavy snow (precipitation rate $>$ 25 g/dm$^2$/h).

The snow column is used 70 percent of the time. As was shown in Section 4, 74 percent of the snow precipitation was considered light (precipitation rate$<$10 g/dm$^2$/h). Consideration should be given to expanding the snow column to encompass the intensity of precipitation (light snow, moderate snow, and heavy snow).

The following is a list of other potential changes to the HOT table columns:

- **Freezing Fog**: Since the use of this column is not extensive and because the times are generally higher than those required for operations, consideration should be given to removing the range and using one value.
- **Frost**: Because the Type II/IV fluid times are very long and the cost of testing is very high, consideration should be given to joining and posting the same times at warm temperatures. For example, the endurance times at 0°C and -3°C are likely to be above the current 12 hour test limit in both cases.
- **Freezing Drizzle**: Consideration should be given to the use of one value rather than a range, particularly because this condition has a low utilization.
- **Light Freezing Rain**: Consideration should be given to the use of one value rather than a range, because this condition has a low utilization and also because it has already been broken out into "light" freezing rain.

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# 5. EVALUATION OF FOG AND FROST DEPOSITION RATES IN NATURAL CONDITIONS

This section contains a description of tests conducted over the past four years to collect fog and frost deposition rates in natural conditions. None of these tests were conducted during winter 2000-01.

## 5.1 Study to Quantify Freezing Fog Deposition Rates

The objective of this study was to calculate and correlate the range of deposition rates that occurs naturally in fog, with the 2 g/dm$^2$/h to 5 g/dm$^2$/h range being used in environmental chambers. The procedure for fog deposition trials appears in Appendix F. The tests were conducted during the 1999-2000 season. For a full account of these tests see Transport Canada report TP 13659E, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance time Testing Program for the 1999-2000 Winter,* Section 6.4 (12).

During fog deposition trials, the fog was reported as dense, with a maximum visibility of 150 m. The obtained rate of 1.3 g/dm$^2$/h is slightly below the lower precipitation rate limit currently used in holdover time testing in simulated conditions.

## 5.2 Measurement of Frost Deposition Rates in Natural Conditions

The objectives of this study were to:

- Measure frost deposition rates that occur naturally
- Determine whether the rates of frost deposition were surface finish dependent

Frost deposition trials were conducted on several occasions.

First, during winter 1997-98, trials were conducted in February and March 1998 on three occasions at two sites in Montreal. A full description of the frost deposition tests on flat plates can be found in Transport Canada report TP 13314E, *Research on Aircraft Deicing Operation for the 1997/1998 Winter*, Section 3.4 (13).

During winter 1998-1999, frost deposition trials were conducted in December 1998, and in January and February 1999 at the APS Dorval test facility, on three separate occasions. For a full account of these tests, see Transport Canada report TP 13477E, *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1998/1999 Winter*, Section 6.6 (14).

Frost deposition trials were also conducted on three occasions in Thompson, Manitoba, between January and April 2000. The experimental procedure and a full description of these tests can be found in Transport Canada report TP 13659E, Section 6.5 (12).

Table 5.1 summarizes all the data collected from Thompson and Montreal. Refer to Figure 5.1 for a plot of the frost rates from Thompson and Montreal compared with the rates stipulated by Proposed Aerospace Standard AS 5485 (dated October 2000) at the various temperatures.

From the results of these tests, it is possible to conclude that the rate of frost deposition is surface-dependent. As can be seen from the scatter plot, tests conducted on the various surfaces have shown that frost rates achieved at colder temperatures in real-world situations are usually lower. In general, the rates of deposition obtained in tests at Thompson concur with the values observed in frost calibration tests conducted at IREQ for -25°C. These rates are below those proposed for use in Aerospace Standard AS 5485, which is 0.06 g/dm$^2$/h.

**Table 5.1: Summary of Natural Frost Deposition Trials**

| Plate Type / Air Temperature (°C) | 0°C | -5°C | -5.5°C | -6.8°C | -9.3°C | -14°C | -16°C | -19.5°C | -30°C |
|---|---|---|---|---|---|---|---|---|---|
| Aluminium 3.2 mm | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.01 |
| Aluminium 1.6 mm |  | 0 |  |  | 0 |  |  |  |  |
| Painted Aluminium White |  | 0.09 |  |  | 0.07 | 0.06 | 0.07 | 0.03 | 0.01 |
| Painted Aluminium Red |  | 0.05 | 0.07 |  | 0.04 |  | 0.08 |  |  |
| Painted Aluminium Green |  | 0.05 | 0.07 |  |  |  | 0.06 |  |  |
| Painted Aluminium Blue |  |  |  |  | 0.04 |  |  |  |  |
| Painted Aluminium Silver |  |  |  |  |  |  | 0.06 |  |  |
| Aluminium Honey Comb 0.5 mm | 0.06 |  | 0 | 0.06 |  |  |  |  |  |
| Kevlar Composite | 0.1 |  |  | 0.11 | 0.07 |  |  |  |  |
| Kevlar/Aramid Honeycomb Composite |  |  |  |  |  | 0.1 |  | 0.04 | 0.04 |
| Carbon Fibre Honeycomb Composite |  |  |  |  |  | 0.09 |  | 0.04 | 0.03 |
| Carbon Fibre Composite |  |  | 0.19 |  |  |  | 0.1 |  |  |
| Carbon Fibre Composite Silver |  |  | 0.17 |  |  |  |  |  |  |

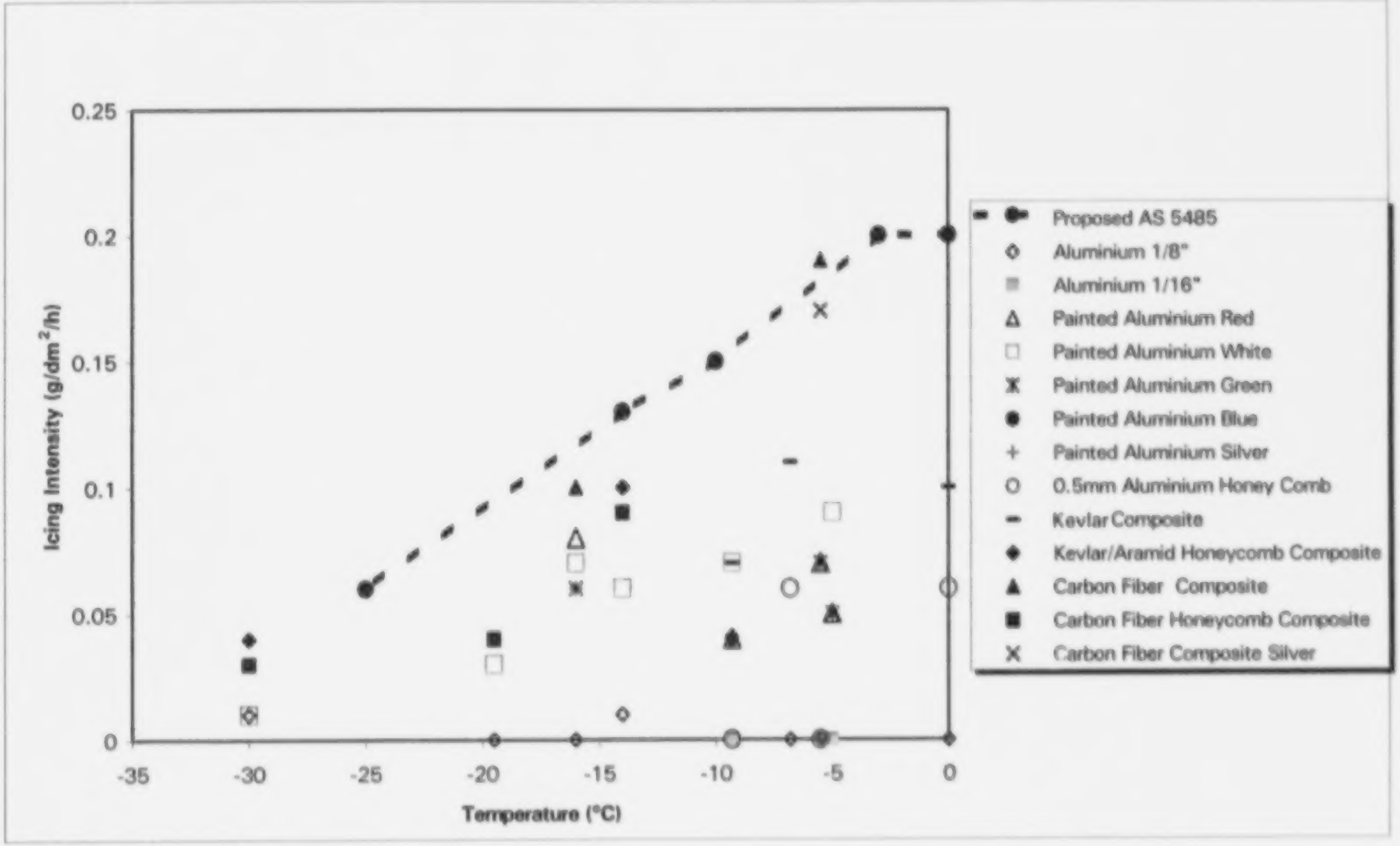

Figure 5.1: Natural Frost Deposition Rates from Montreal 1997-1999 and Thompson 1999-2000

# 6. CONCLUSIONS

## 6.1 Natural Snow and Freezing Rain / Drizzle

The data shown and analyzed in this report include six acquisition sites for a period of five years. The data analysis indicates that the current holdover time rate evaluation limits of 10 g/dm$^2$/h and 25 g/dm$^2$/h for snow are satisfactory. In the -14°C to -25°C range, the 95th percentile was 22 g/dm$^2$/h.

The majority of the limited data on freezing rain/drizzle were centred in the -3°C to -5°C interval. The 95th percentile precipitation rate from the limited freezing rain/drizzle data was approximately 25 g/dm$^2$/h.

## 6.2 Evaluation of Fog Deposition Rates in Natural Condition

This report contains the results of the natural fog deposition tests. The measured deposition rate of 1.3 g/dm$^2$/h was slightly below the lower precipitation rate limit currently used in holdover time testing in simulated conditions. This indicates that the rates of 2 g/dm$^2$/h and 5 g/dm$^2$/h are probably high. This is particularly true for the fluids with long holdover times (>1 hour) as fog typically requires aircraft taxi movement for a deposition to occur.

## 6.3 Evaluation of Frost Deposition Rates

This report contains a summary of the results from previous tests conducted outdoors to measure icing intensity in frost conditions.

From the results of the frost tests (Montreal and Thompson, Manitoba) it was concluded that the rate of frost deposition is surface-dependent. Icing intensity measured in real-world situations are below those proposed for use in Proposed Aerospace Standard AS 5485.

## 6.4 Evaluation of HOT Table Format

The Type I and Type II/IV HOT table formats have undergone significant change since the early 1990s. While the changes have been made primarily to improve and address the safety concerns of many individuals and organizations involved in the deicing industry, a structured approach has not been taken when implementing the changes. In fact, many of the changes have been made on a year-by-year basis at industry meetings. These changes were typically minor in nature, but after nearly 10 years, the impact on the HOTs is more significant. More recently, a number of industry members have questioned the suitability of the HOT table format. Several proposed suggestions for change have been made to improve and simplify the tables, while at the same time maintaining a high level of safety. Proposed changes could include new temperature breakdowns to better reflect winter precipitation conditions, expansion of the snow column to reflect its high usage, and removal of unnecessary HOT ranges in certain columns, resulting in a single value.

# 7. RECOMMENDATIONS

## 7.1 Natural Snow and Freezing Rain / Drizzle

More data should be collected and analyzed from the six weather stations in Quebec, with emphasis on freezing rain and freezing drizzle.

## 7.2 Fog Deposition Rates in Natural Condition

More natural fog deposition rates should be measured to correlate with the 2 $g/dm^2/h$ to 5 $g/dm^2/h$ range being used in environmental chambers.

## 7.3 Frost Deposition Rates

The icing intensities required by Proposed Aerospace Standard AS 5485 should be evaluated. Further tests should be conducted to establish the parameters that exist in the real world.

## 7.4 HOT Table Format

The Co-Chairs of the SAE-G12 HOT subcommittee set up a workgroup on weather to evaluate and propose changes to the HOT table breakdown and format. Further analysis should be carried out to support any proposed changes.

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11. Environment Canada, Atmospheric Environment Service, 1983: *Principal Station Data, MONTREAL INT'L A.*

12. Chaput, M., Hanna, M., and Hunt, M., 2000: *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2000, TP 13659E (to be published).

13. Chaput, M., Dawson, P., D'Avirro, J., Hanna, M., Ruggi, E., Adam, S., and Pole, C., 1998: *Research on Aircraft De-icing Operations for the 1997/98 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, TP 13314E, 132.

14. Chaput, M., Hanna, M., Peters, A., Hunt, M., and Ruggi, E., 1999: *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1998/99 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, TP 13477E (to be published).

# APPENDIX A

## WORK STATEMENT (EXCERPT)

## PROJECT DESCRIPTION

# PROJECT DESCRIPTION EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

## AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
## 2000 -2001
## (January 2001)

## 5.1.6 EVALUATION OF WINTER WEATHER DATA

A study of the snow weather data has been undertaken since 1995 to ascertain the suitability of the precipitation rate ranges used for fluid holdover time evaluation in snow. Winter weather data will be collected and examined from Environment Canada for six weather stations within Quebec (Dorval, Quebec City, Rouyn, Pointe-au-Père, Frelighsburg, and High Falls).

During the 1999-2000 test season, APS collected one fog deposition measurement in an attempt to determine typical fog deposition rates that occur in natural conditions. The observed rate of fog deposition was below the current lower precipitation rate used in the evaluation of fluid holdover times in this condition.

### 5.1.6.1 Snow Rates

5.1.6.1.1 Examine the precipitation rate/temperature data from the different stations to determine the variance of the data in warmer and colder regions.

5.1.6.1.2 Examine the various temperature ranges used to establish holdover times to determine the frequency of precipitation that occurs within each temperature range.

5.1.6.1.3 Analyze the data collected and report the findings.

### 5.1.6.2 Fog Deposition Rates

5.1.6.2.1 Prepare a procedure for the collection of fog deposition rates in natural fog conditions.

5.1.6.2.2 Collect fog deposition measurements on at least two occasions.

5.1.6.2.3 Analyze the data collected and report the findings.

# APPENDIX B

## WINTER WEATHER DATA 1995 to 2001

# WINTER WEATHER DATA

## 1995 TO 2001

The following charts include the complete rate data analysis, subdivided by temperature ranges for both snow and freezing rain. A histogram of points and a cumulative probability chart are included for each rate calculation interval in all temperature ranges.

The lowest holdover time temperature range for snow conditions was subdivided into three ranges. The charts for this analysis are also included.

## INDEX

**SNOW**

Above 0°C, 35-minute rates .......... B-2
Above 0°C, 20-minute rates .......... B-4
Above 0°C, 6-minute rates .......... B-6
0 to -3°C, 35-minute rates .......... B-8
0 to -3°C, 20-minute rates .......... B-10
0 to -3°C, 6-minute rates .......... B-12
-3 to -7°C, 35-minute rates .......... B-14
-3 to -7°C, 20-minute rates .......... B-16
-3 to -7°C, 6-minute rates .......... B-18
-7 to -14°C, 35-minute rates .......... B-20
-7 to -14°C, 20-minute rates .......... B-22
-7 to -14°C, 6-minute rates .......... B-24
-14 to -25°C, 35-minute rates .......... B-26
-14 to -25°C, 20-minute rates .......... B-28
-14 to -25°C, 6-minute rates .......... B-30

**LIGHT FREEZING RAIN**

0 to -3°C, 35-minute rates .......... B-32
0 to -3°C, 20-minute rates .......... B-34
0 to -3°C, 6-minute rates .......... B-36
-3 to -10°C, 35-minute rates .......... B-38
-3 to -10°C, 20-minute rates .......... B-40
-3 to -10°C, 6-minute rates .......... B-42

**COLD SNOW SUBDIVISION**

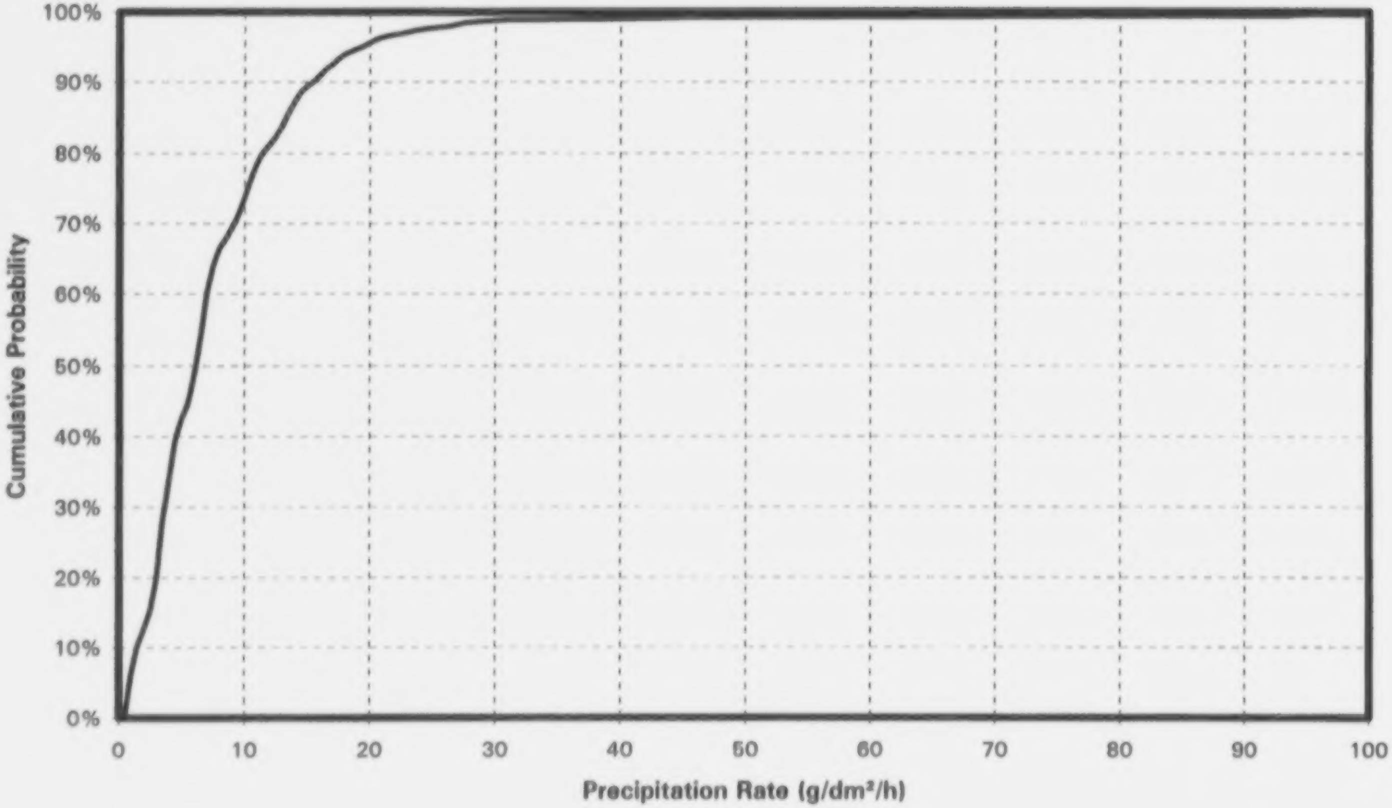
-14 to -18°C, 35-minute rates .......... B-44
-14 to -18°C, 20-minute rates .......... B-46
-14 to -18°C, 6-minute rates .......... B-48
-18 to -22°C, 35-minute rates .......... B-50
-18 to -22°C, 20-minute rates .......... B-52
-18 to -22°C, 6-minute rates .......... B-54
-22 to -25°C, 35-minute rates .......... B-56
-22 to -25°C, 20-minute rates .......... B-58
-22 to -25°C, 6-minute rates .......... B-60

## READAC AND CR21X ANALYSIS - NATURAL SNOW

## ABOVE 0°C

### 35-MINUTE RATE EVERY MINUTE

### 1995-2001

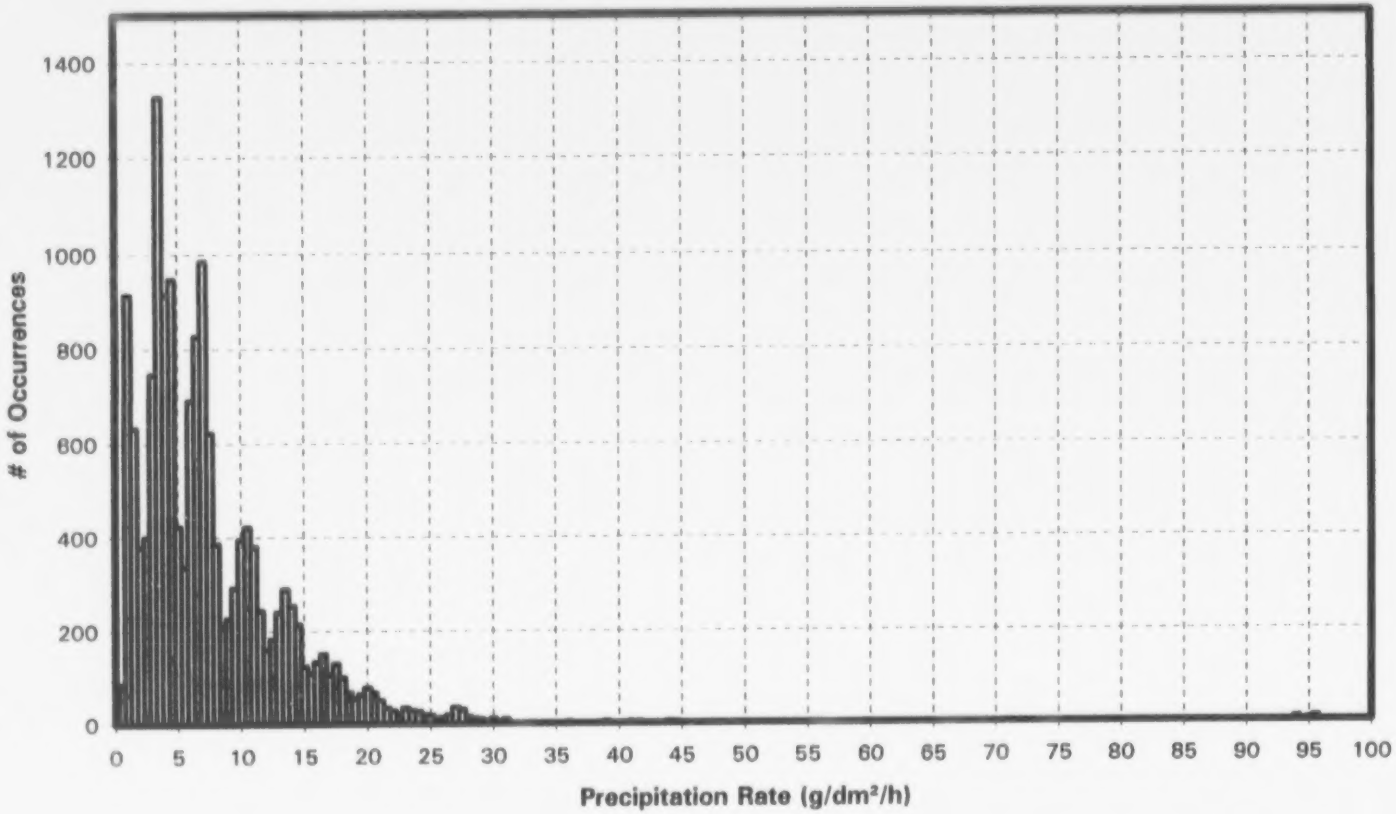


READADAC AND CR21X ANALYSIS - NATURAL SNOW

**ABOVE 0°C**

**35-MINUTE RATE EVERY MINUTE**

**1995-2001**

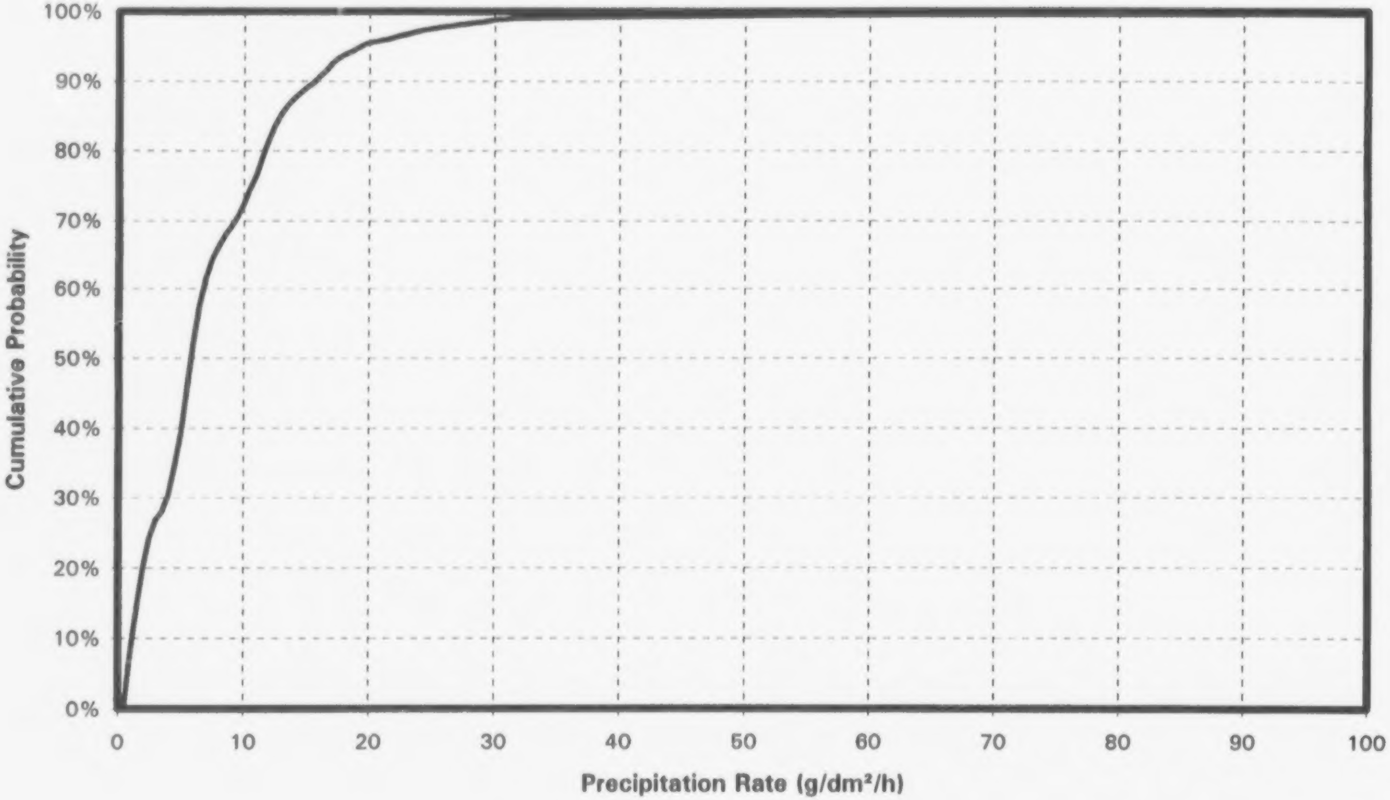


READAC AND CR21X ANALYSIS - NATURAL SNOW

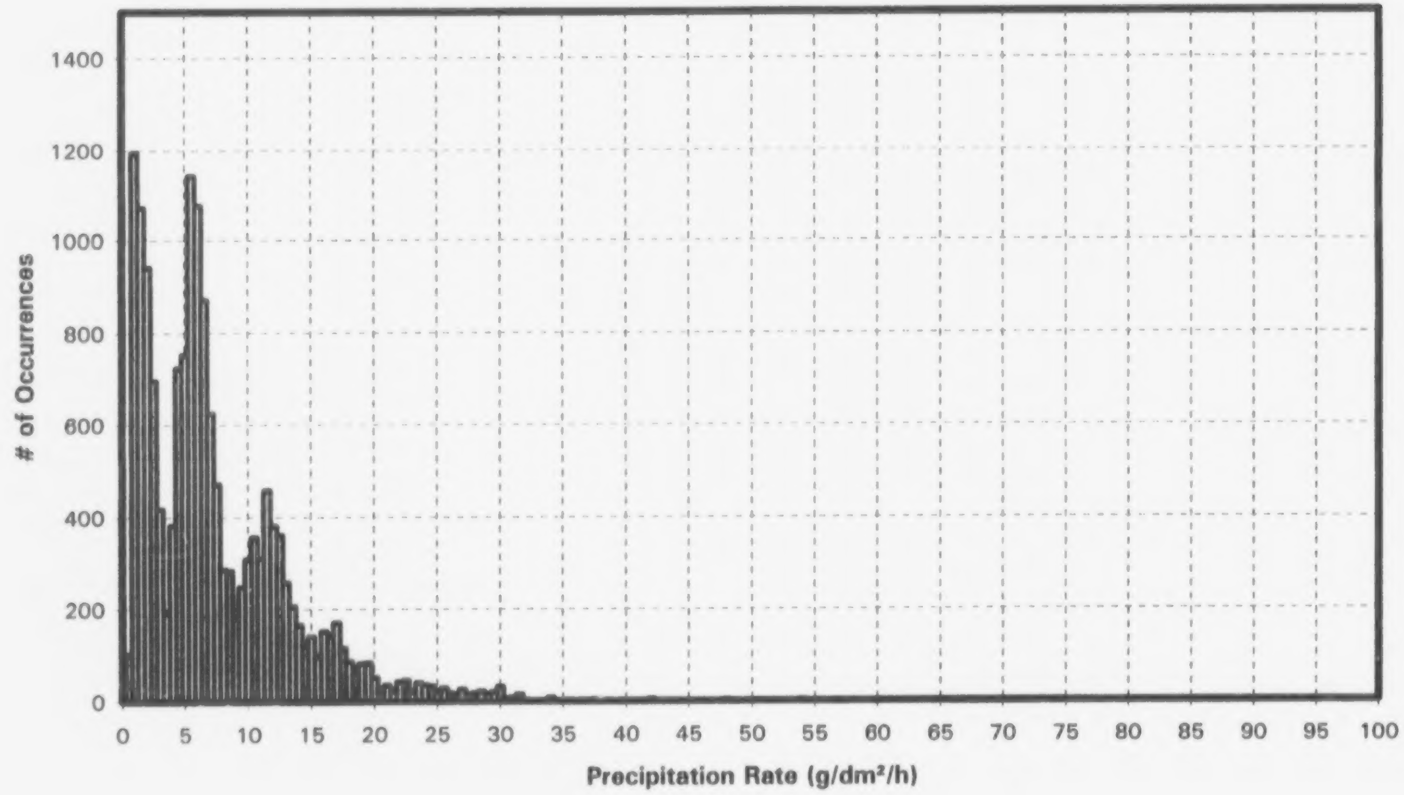
**ABOVE 0°C**

**20-MINUTE RATE EVERY MINUTE**

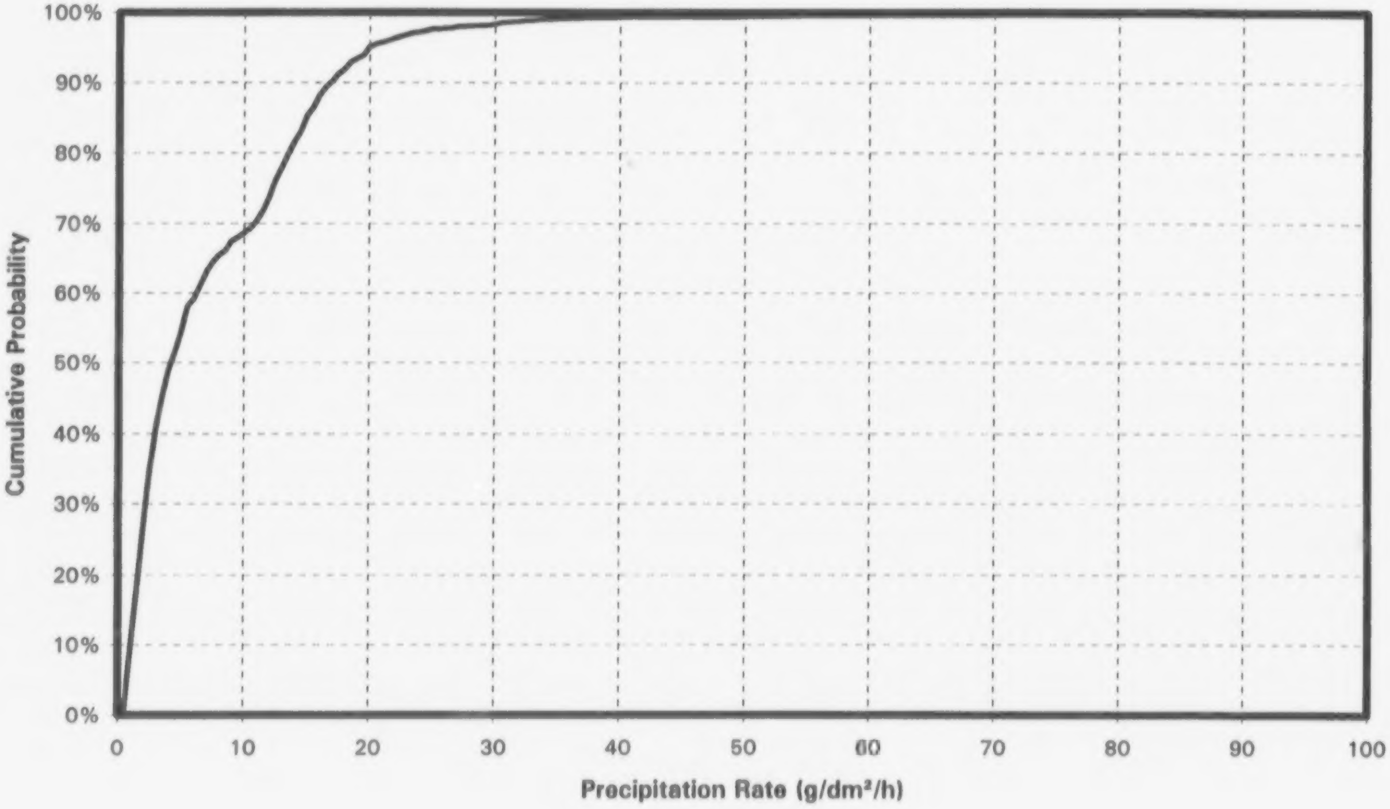
**1995-2001**



READADC AND CR21X ANALYSIS - NATURAL SNOW
**ABOVE 0°C**
**20-MINUTE RATE EVERY MINUTE**
**1995-2001**



## READADC AND CR21X ANALYSIS - NATURAL SNOW
## ABOVE 0°C
### 6-MINUTE RATE EVERY MINUTE
### 1995-2001

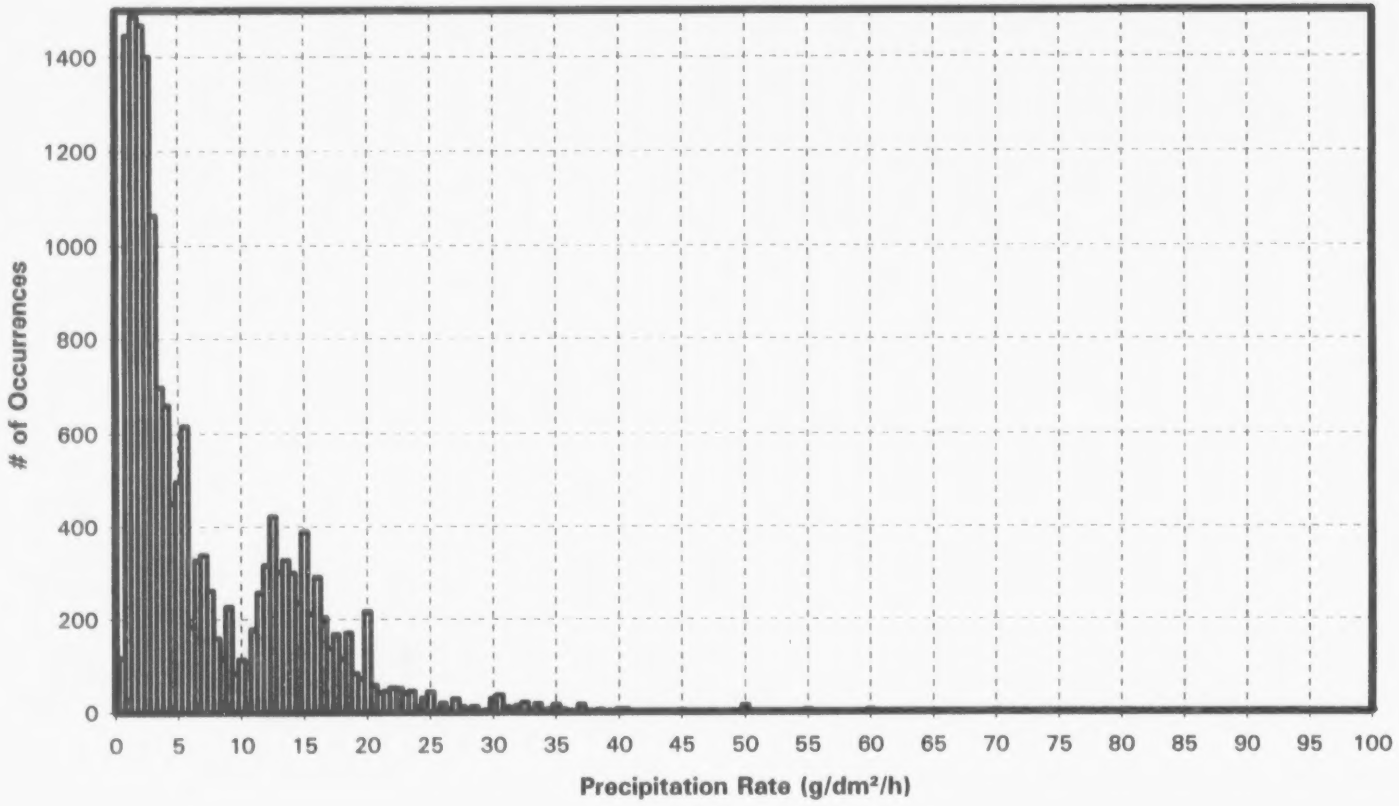


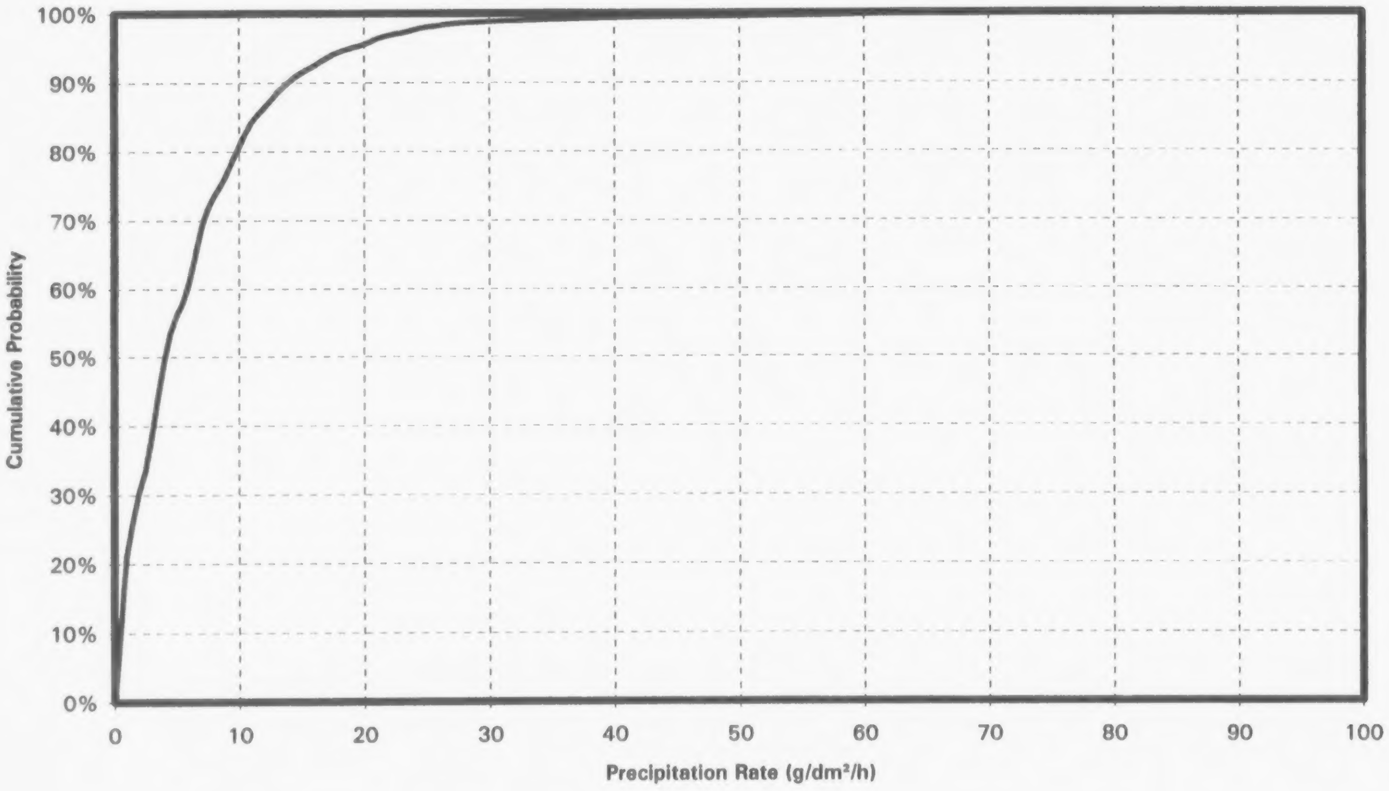
## READAC AND CR21X ANALYSIS - NATURAL SNOW

## ABOVE 0°C

### 6-MINUTE RATE EVERY MINUTE

### 1995-2001





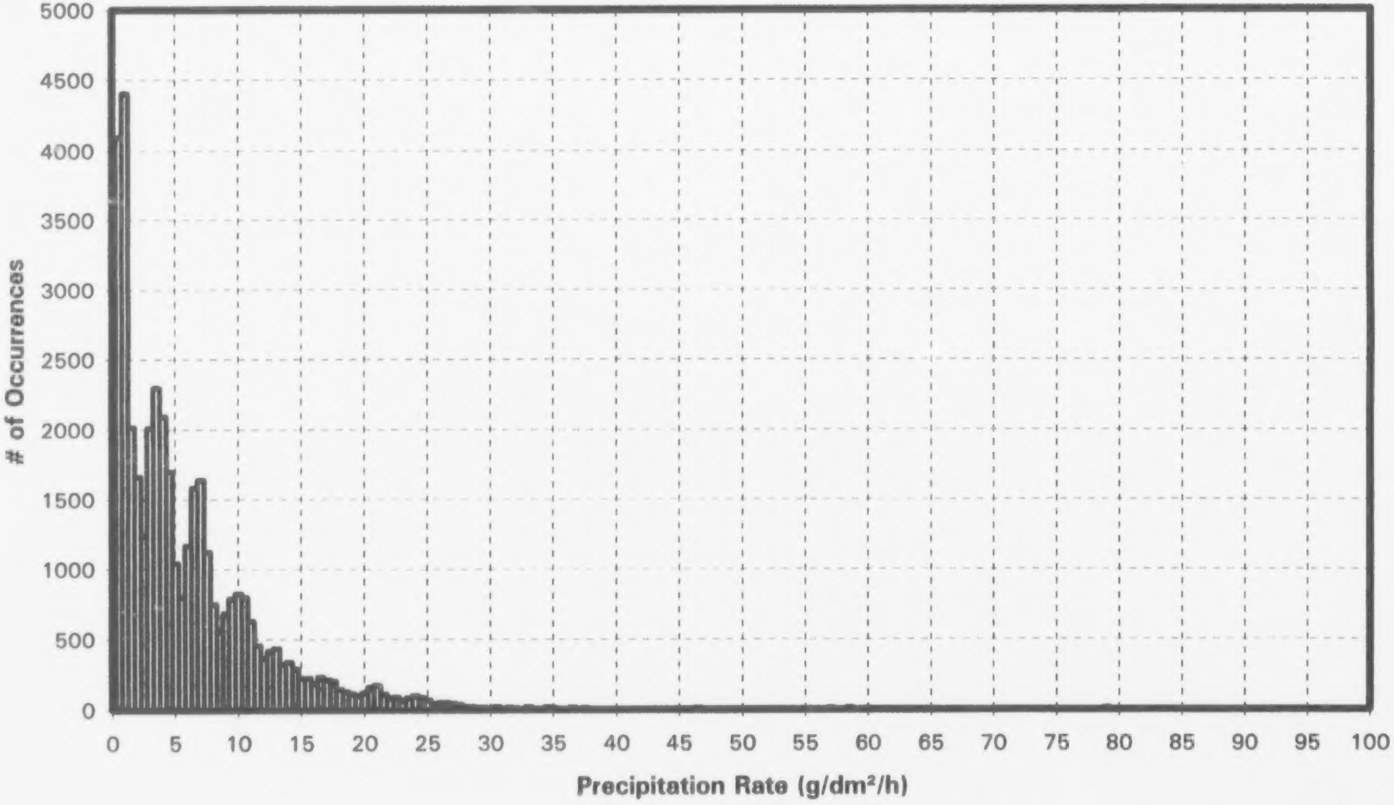
READADC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

**35-MINUTE RATE EVERY MINUTE**

**1995-2001**

READAC AND CR21X ANALYSIS - NATURAL SNOW
0 TO -3°C
35-MINUTE RATE EVERY MINUTE
1995-2001

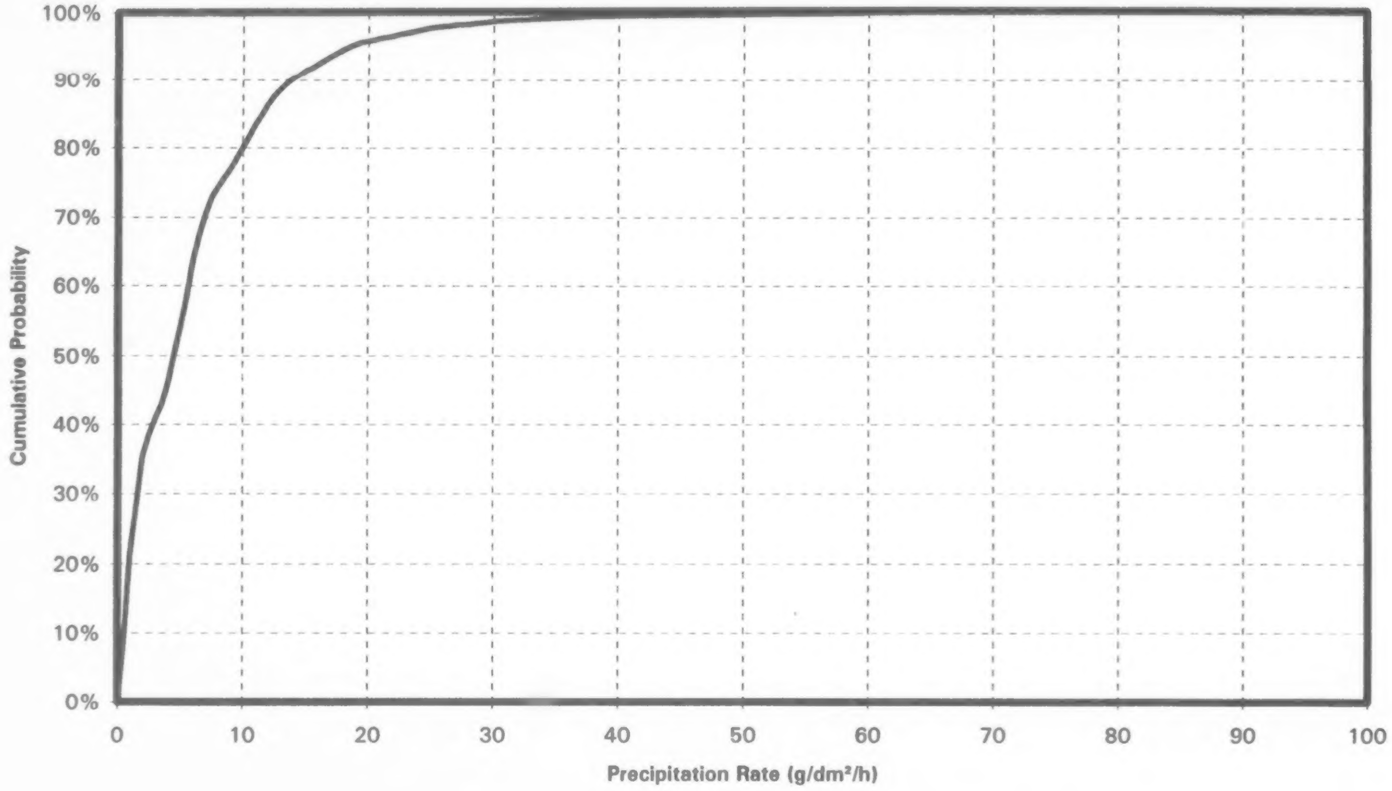


READADAC AND CR21X ANALYSIS - NATURAL SNOW

**0 TO -3°C**

**20-MINUTE RATE EVERY MINUTE**

**1995-2001**



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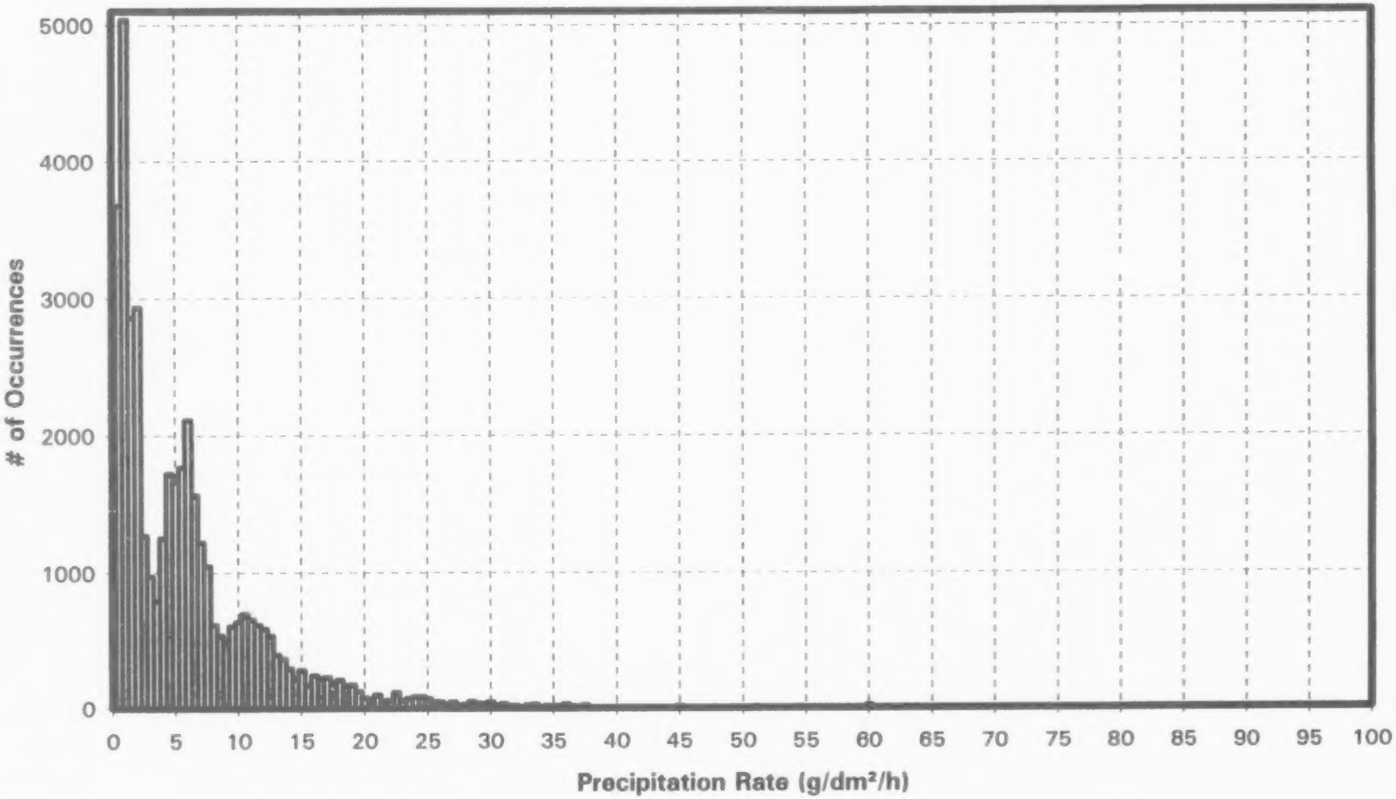
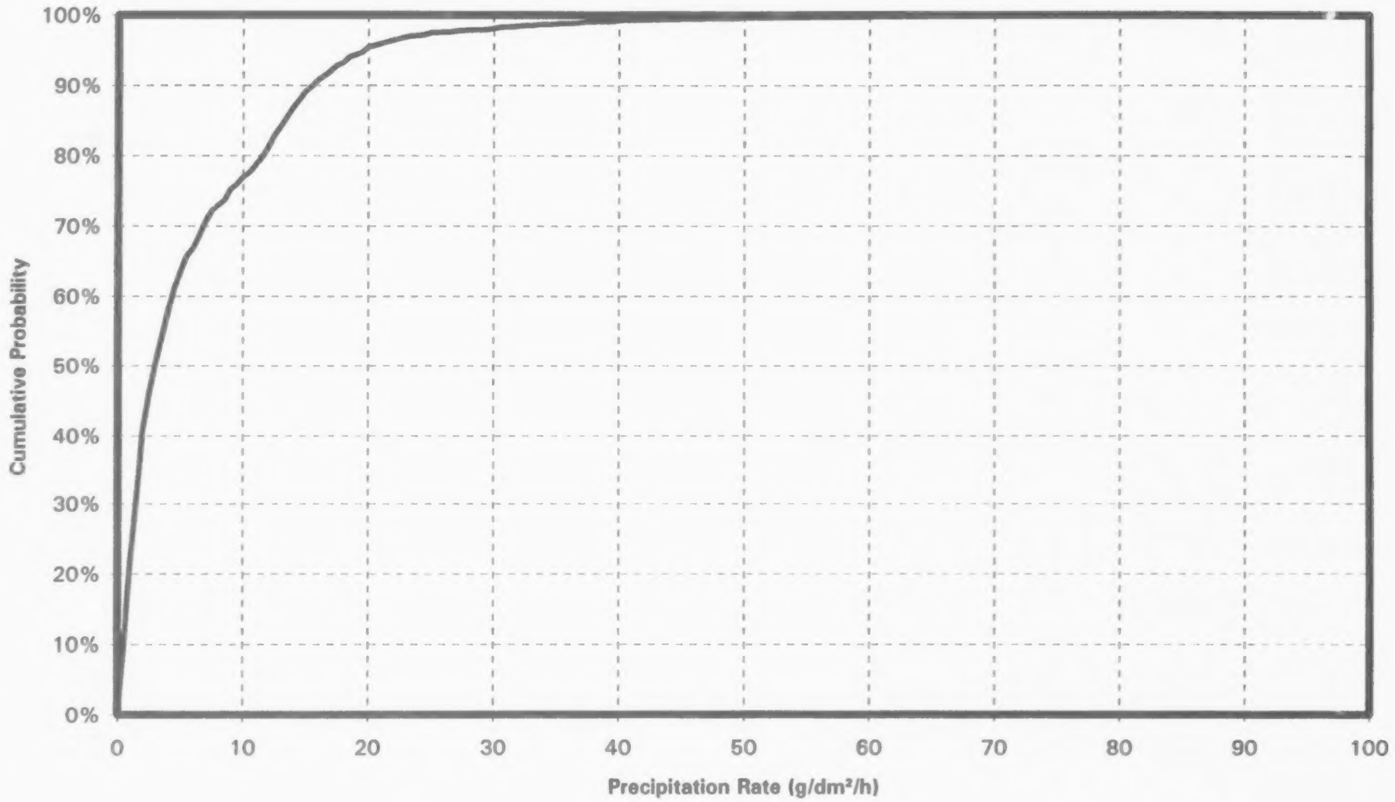
## 0 TO -3°C
## 20-MINUTE RATE EVERY MINUTE
## 1995-2001



READADC AND CR21X ANALYSIS - NATURAL SNOW
**0 TO -3°C**
**6-MINUTE RATE EVERY MINUTE**
**1995-2001**

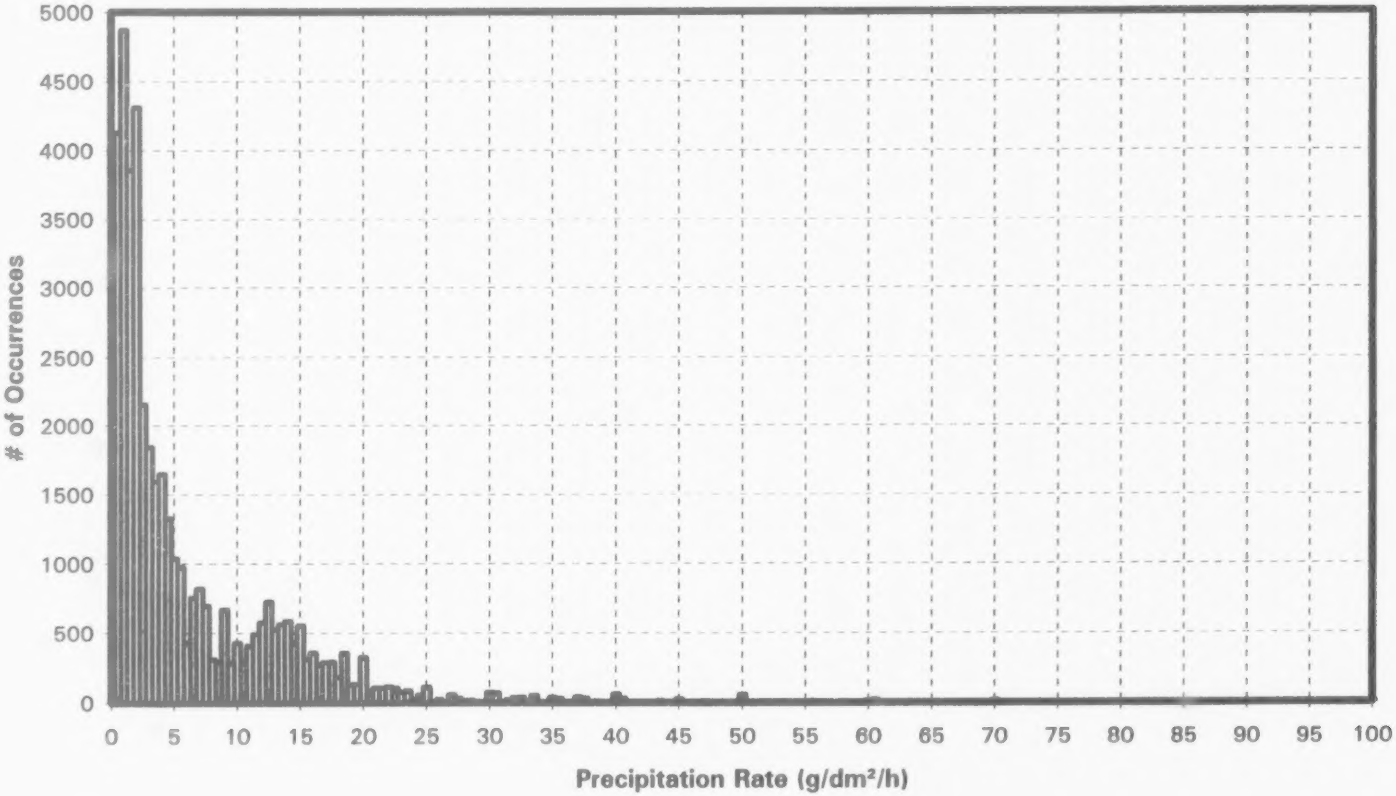


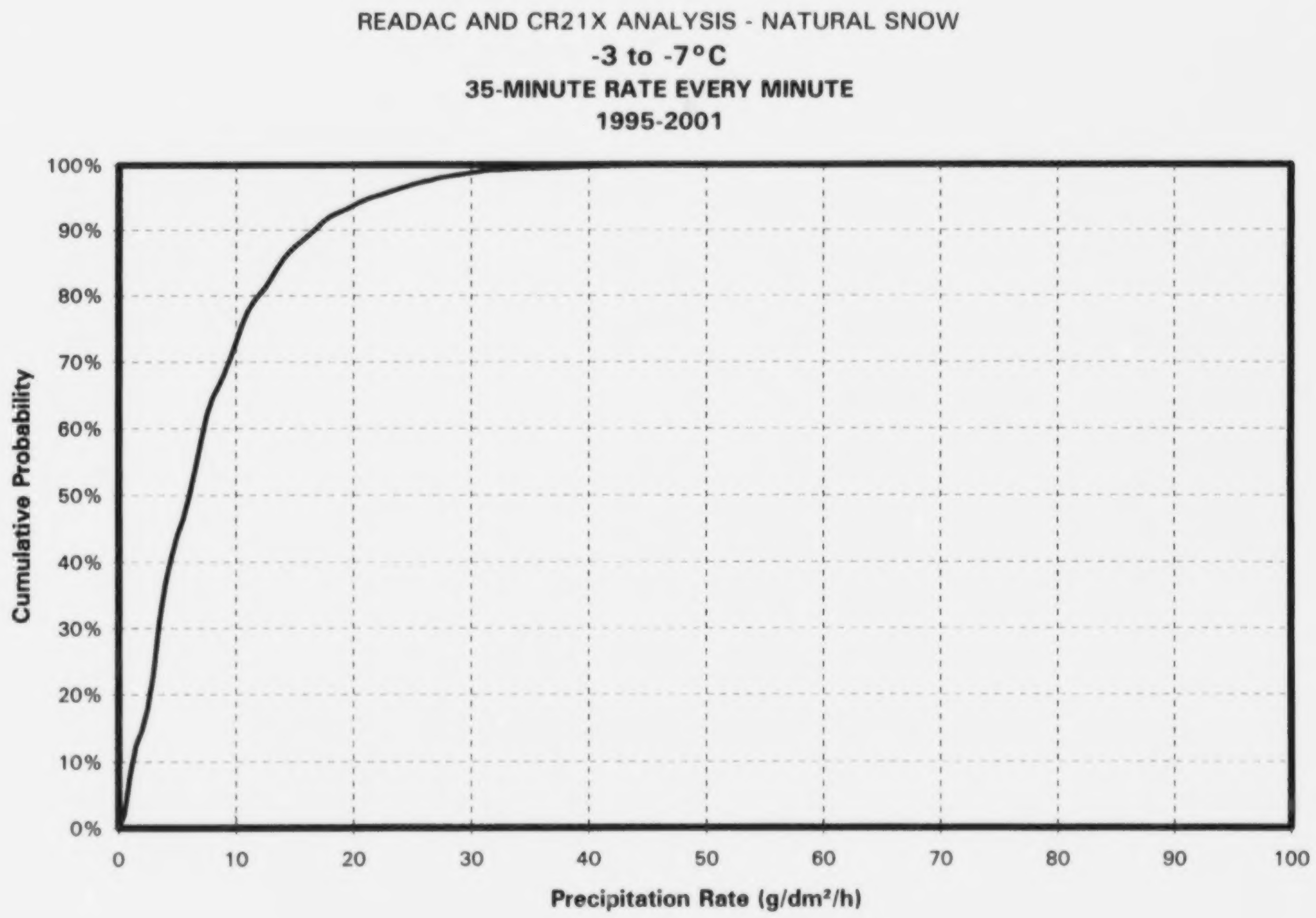
READADAC AND CR21X ANALYSIS - NATURAL SNOW

**0 TO -3°C**

**6-MINUTE RATE EVERY MINUTE**

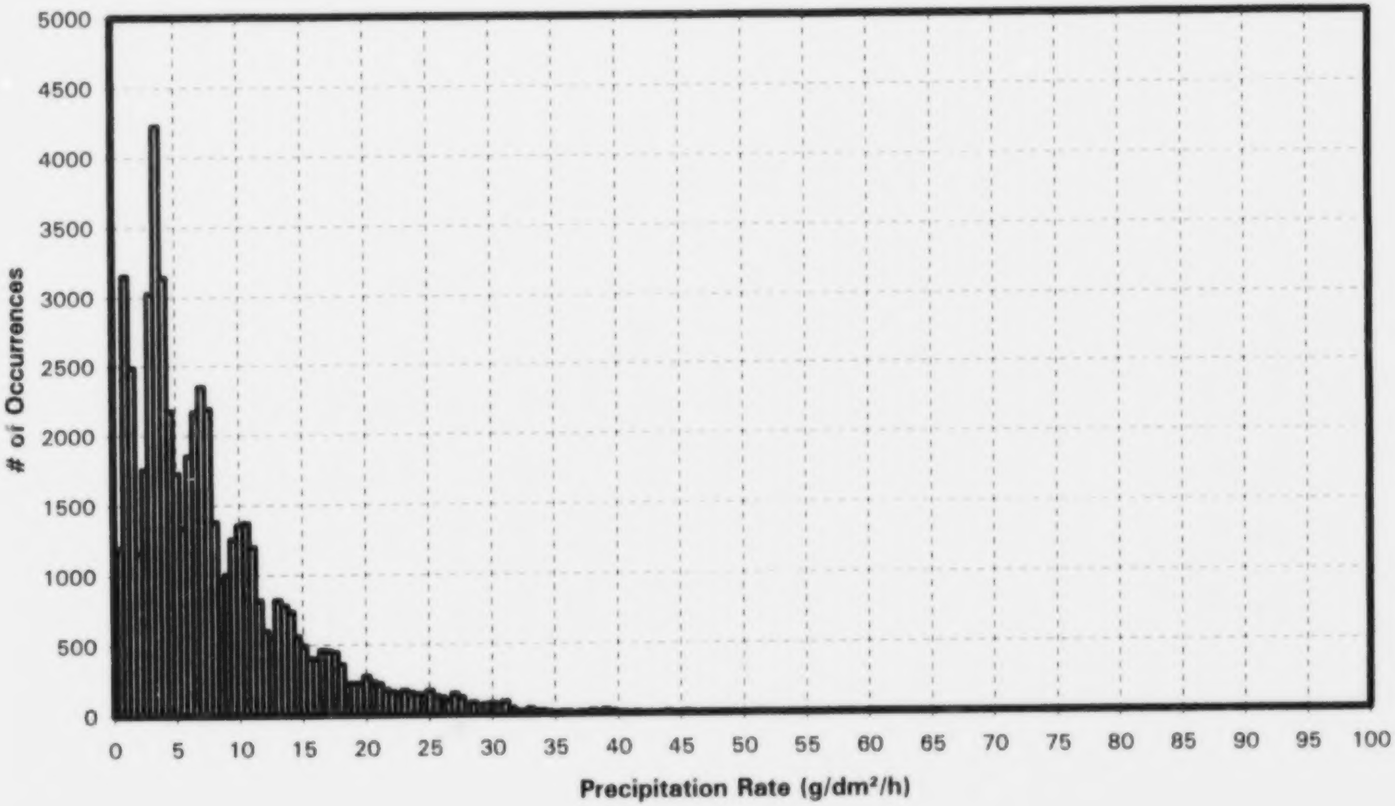
**1995-2001**



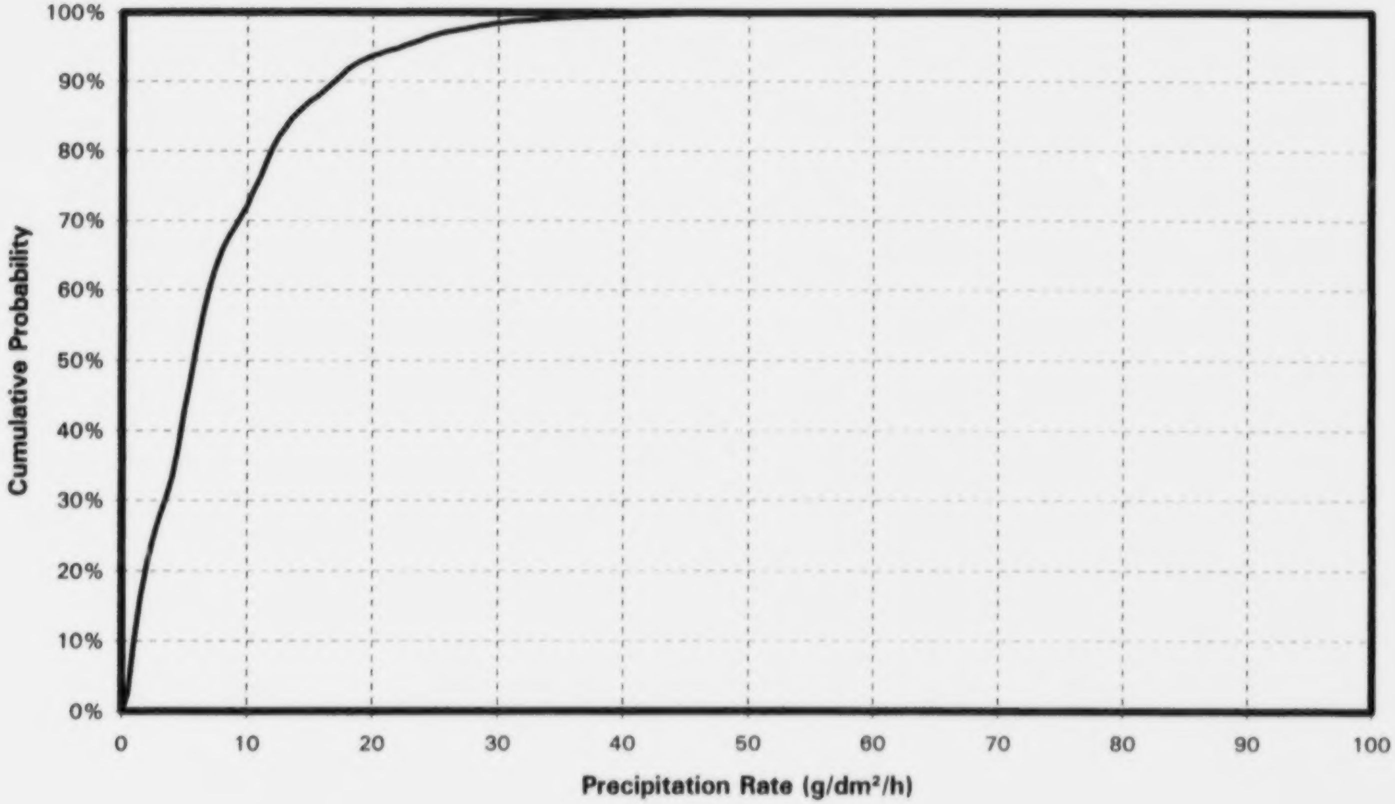


READADC AND CR21X ANALYSIS - NATURAL SNOW
-3 to -7°C
35-MINUTE RATE EVERY MINUTE
1995-2001

## READAC AND CR21X ANALYSIS - NATURAL SNOW
## -3 TO -7°C
## 35-MINUTE RATE EVERY MINUTE
## 1995-2001



READADC AND CR21X ANALYSIS - NATURAL SNOW
-3 TO -7°C
20-MINUTE RATE EVERY MINUTE
1995-2001

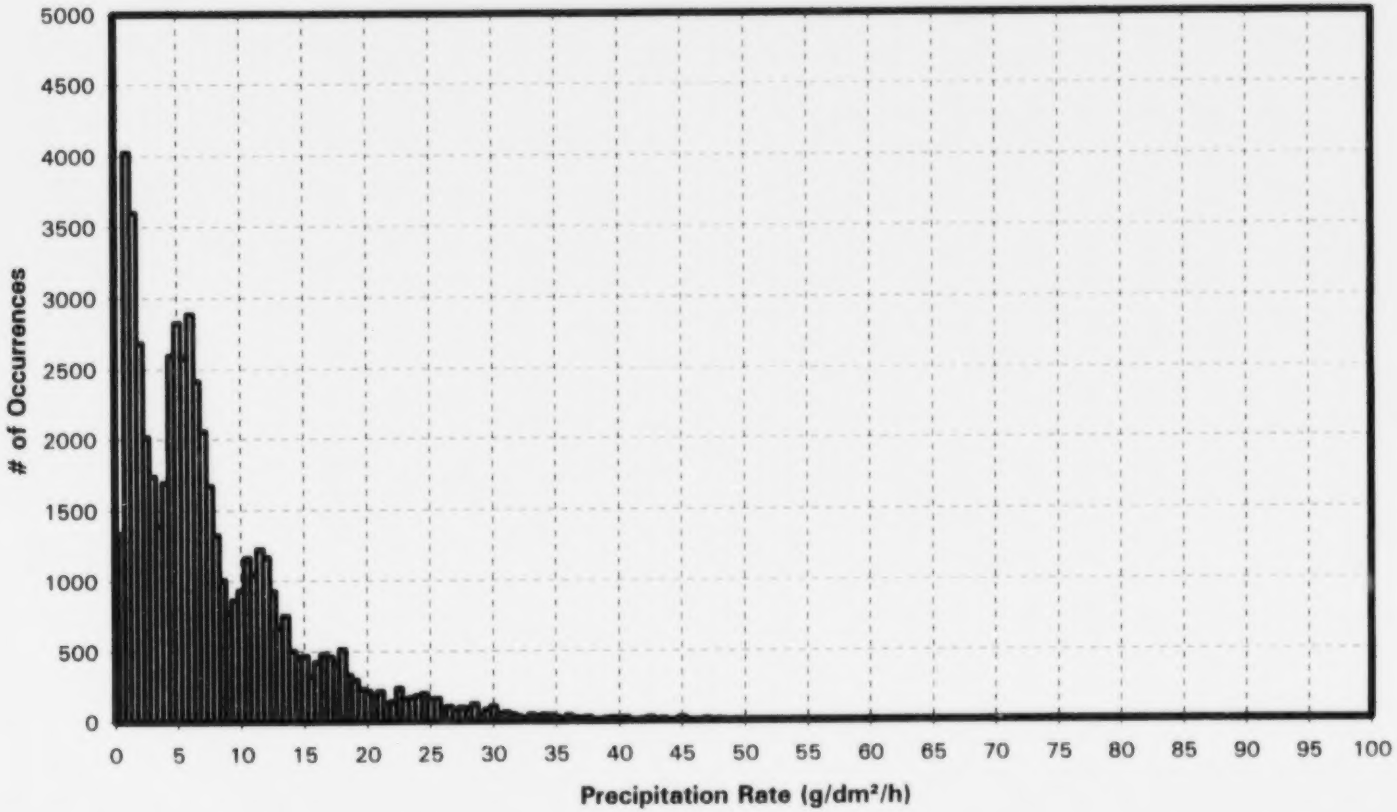


READAC AND CR21X ANALYSIS - NATURAL SNOW

**-3 TO -7°C**

**20-MINUTE RATE EVERY MINUTE**

**1995-2001**

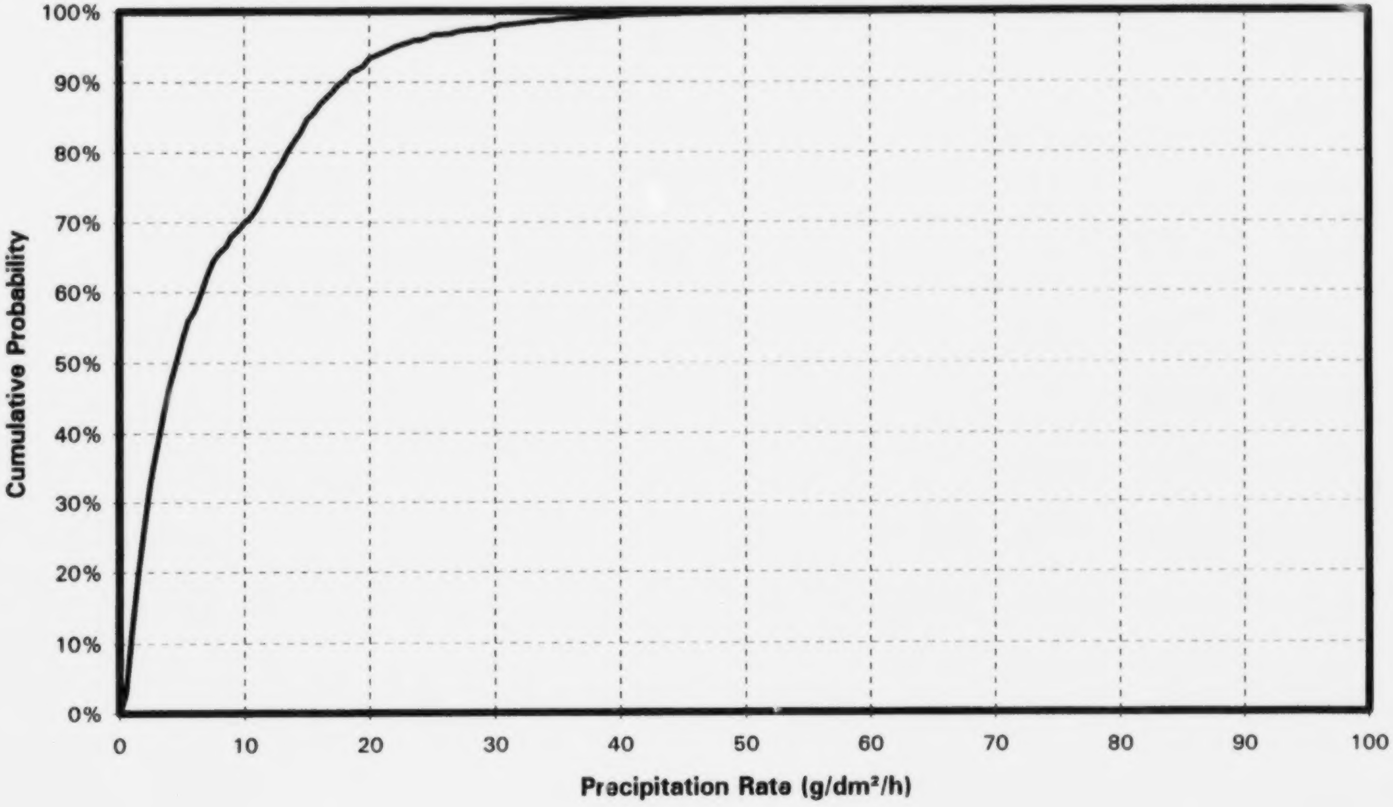


READADC AND CR21X ANALYSIS - NATURAL SNOW

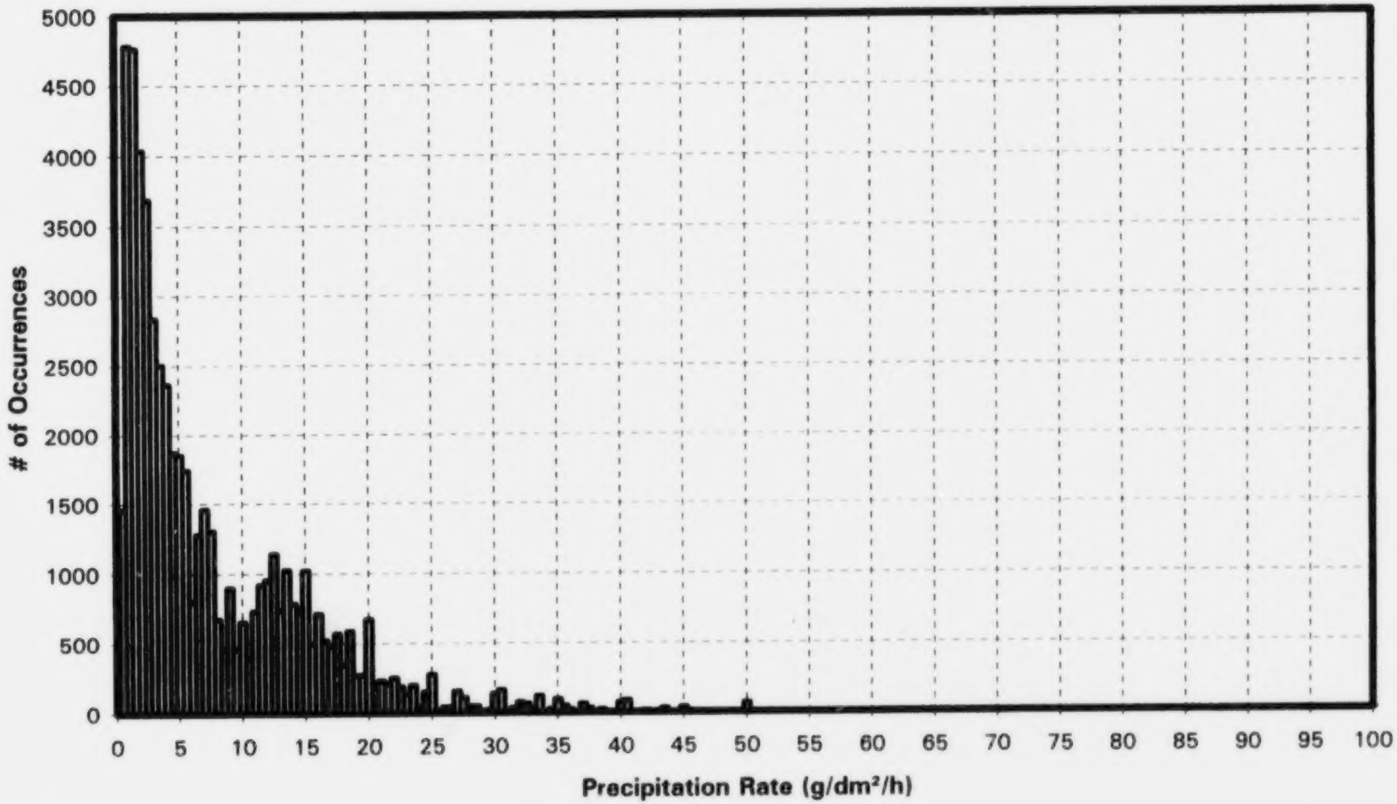
**-3 TO -7°C**

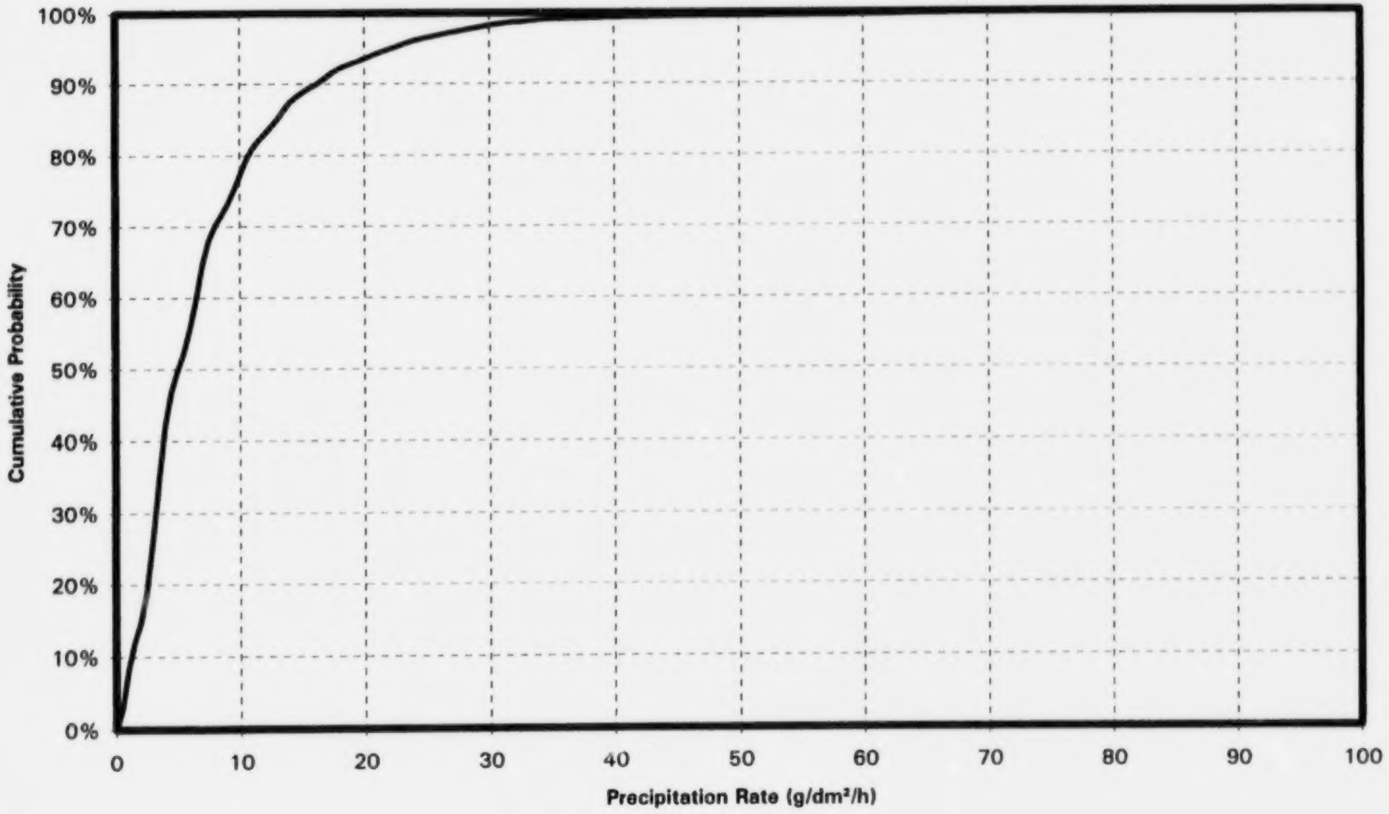
**6-MINUTE RATE EVERY MINUTE**

**1995-2001**



### READAC AND CR21X ANALYSIS - NATURAL SNOW
### -3 TO -7°C
### 6-MINUTE RATE EVERY MINUTE
### 1995-2001





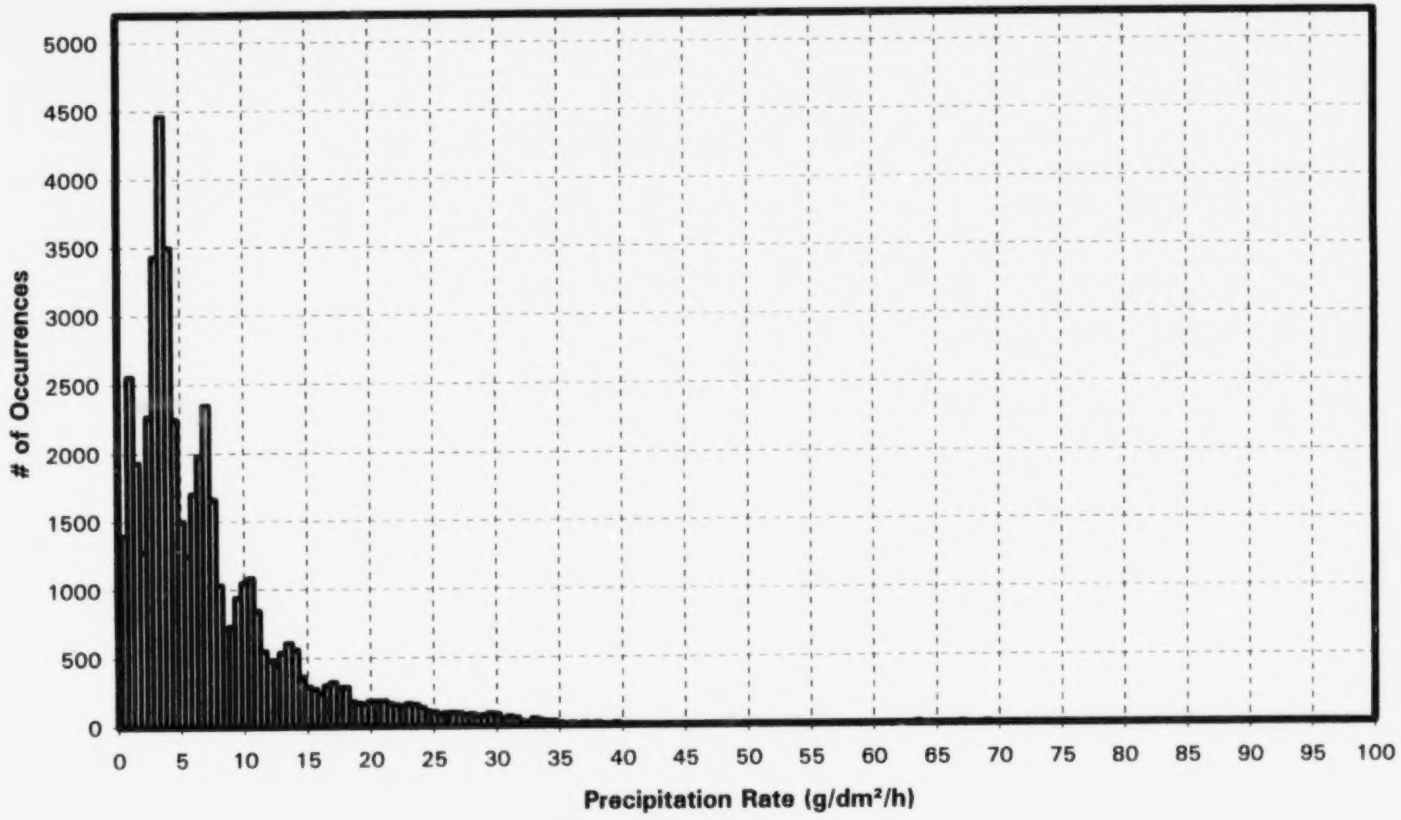
READADC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

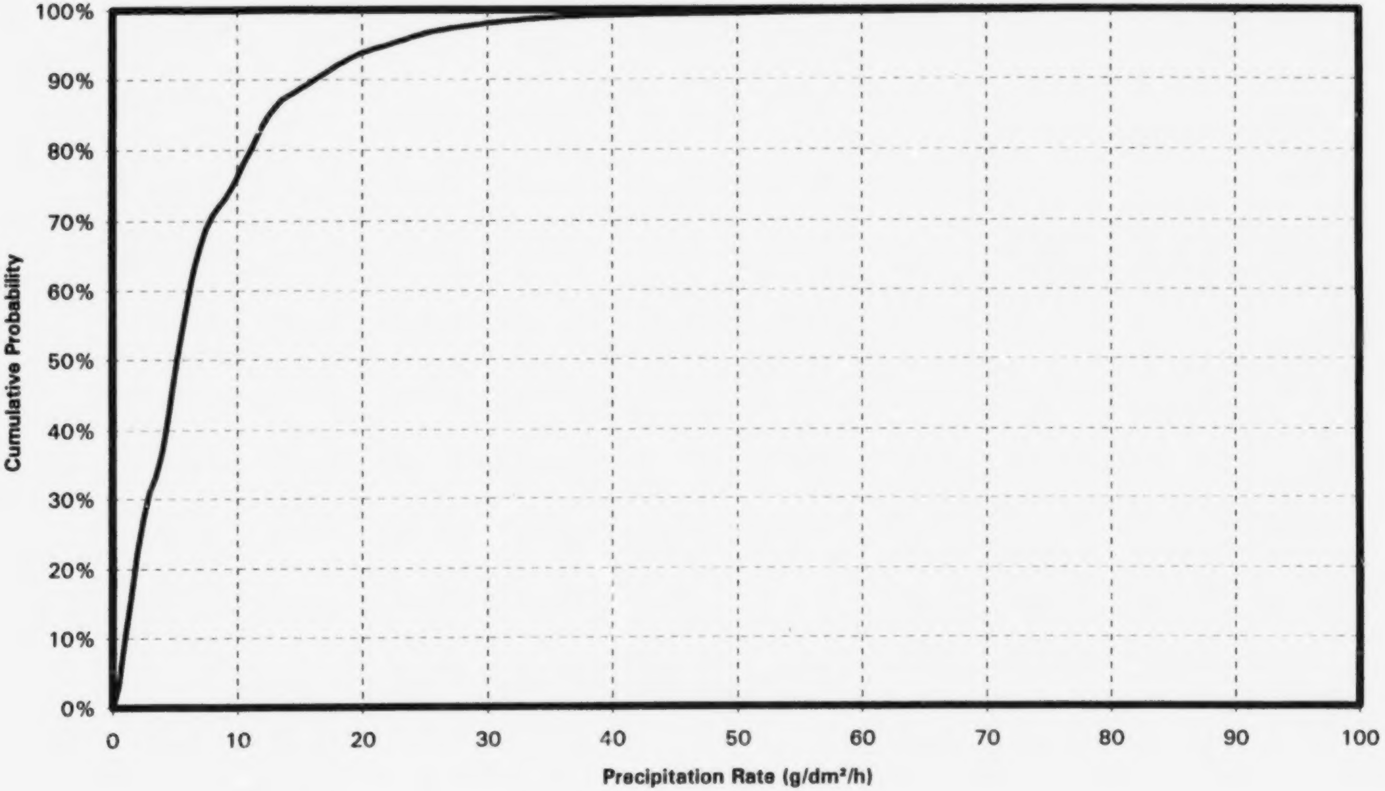
**35-MINUTE RATE EVERY MINUTE**

**1995-2001**

## READAC AND CR21X ANALYSIS - NATURAL SNOW
### -7 TO -14°C
### 35-MINUTE RATE EVERY MINUTE
### 1995-2001



READAC AND CR21X ANALYSIS - NATURAL SNOW
**-7 TO -14°C**
**20-MINUTE RATE EVERY MINUTE**
**1995-2001**



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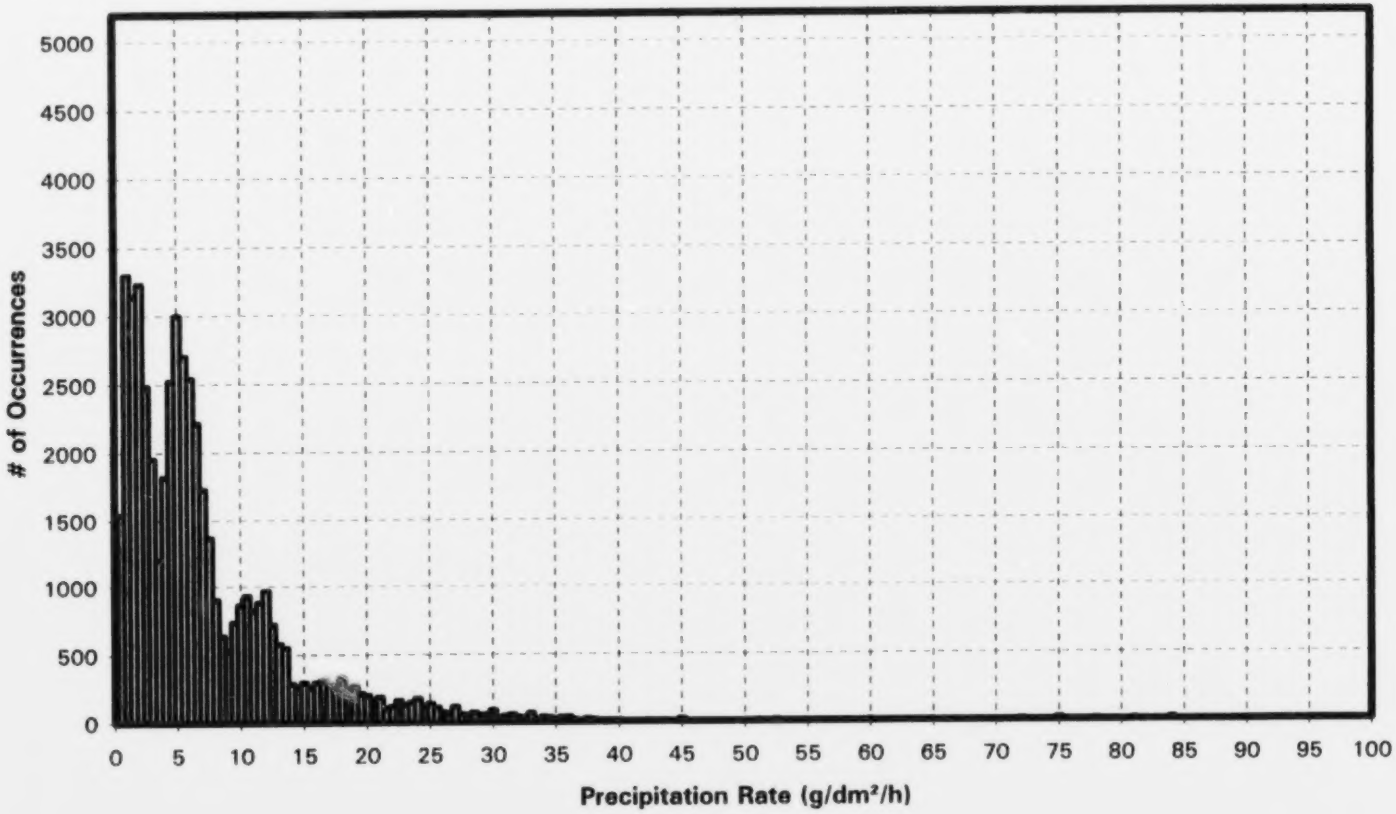
## -7 TO -14°C
### 20-MINUTE RATE EVERY MINUTE
### 1995-2001

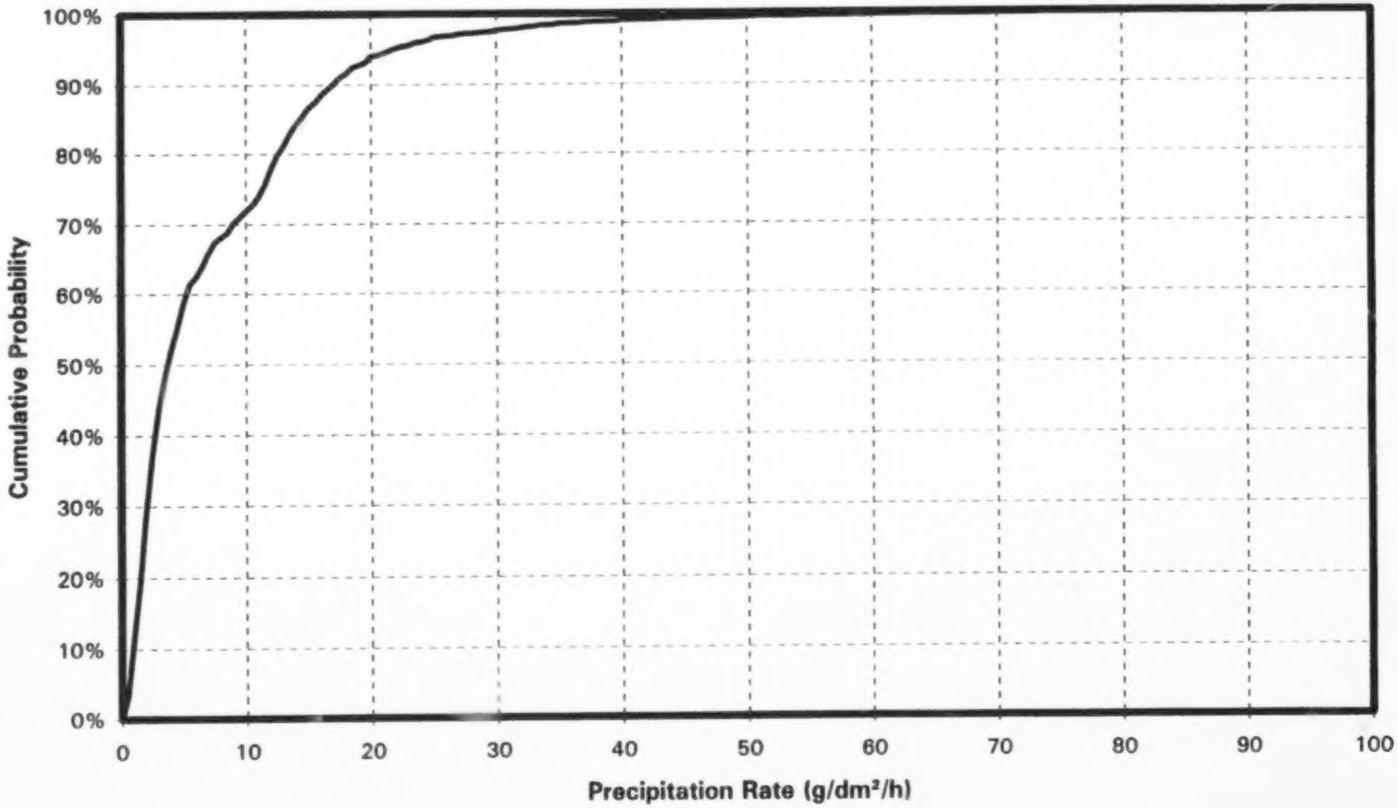


READAC AND CR21X ANALYSIS - NATURAL SNOW

**-7 TO -14°C**

**6-MINUTE RATE EVERY MINUTE**

**1995-2001**

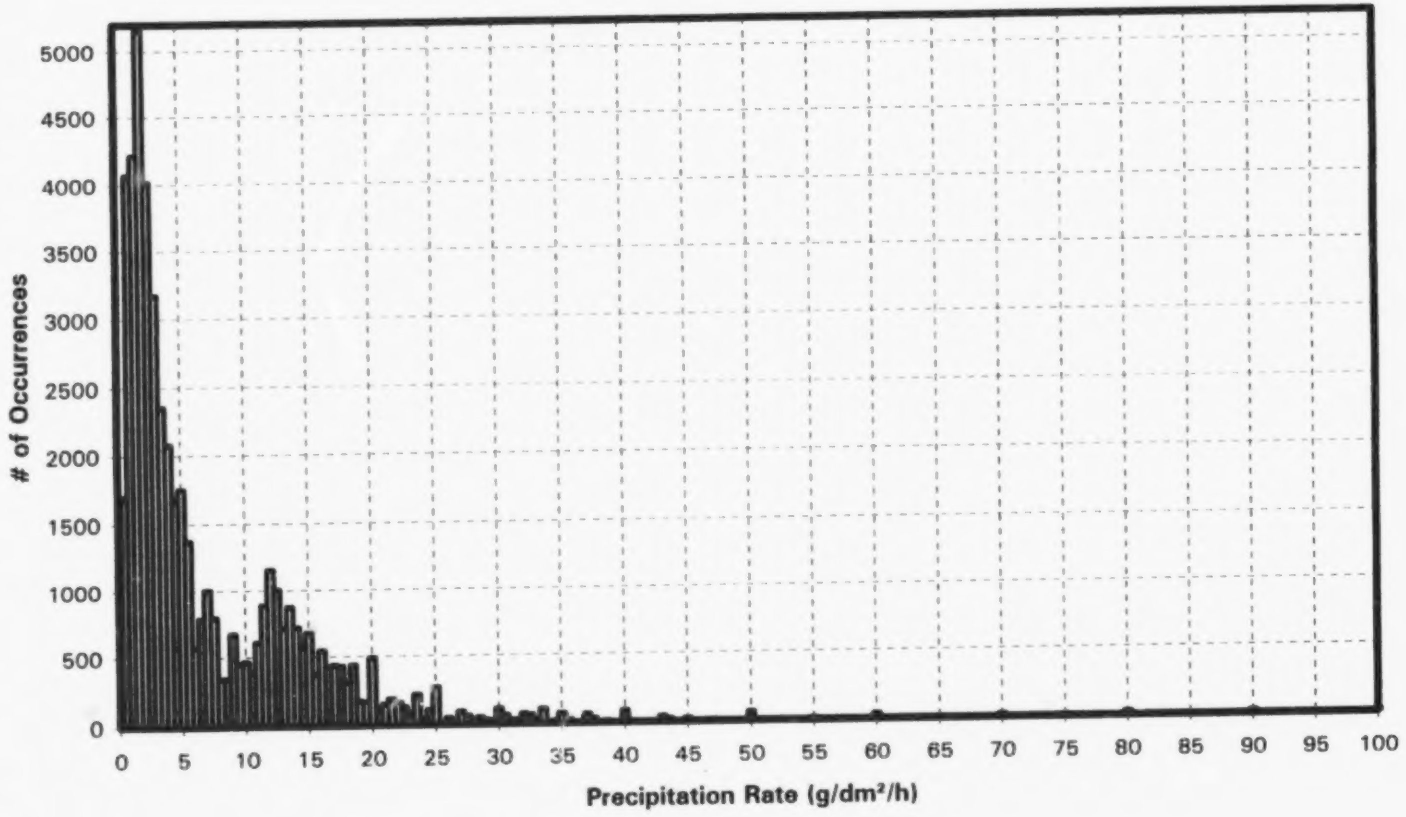


## READADC AND CR21X ANALYSIS - NATURAL SNOW

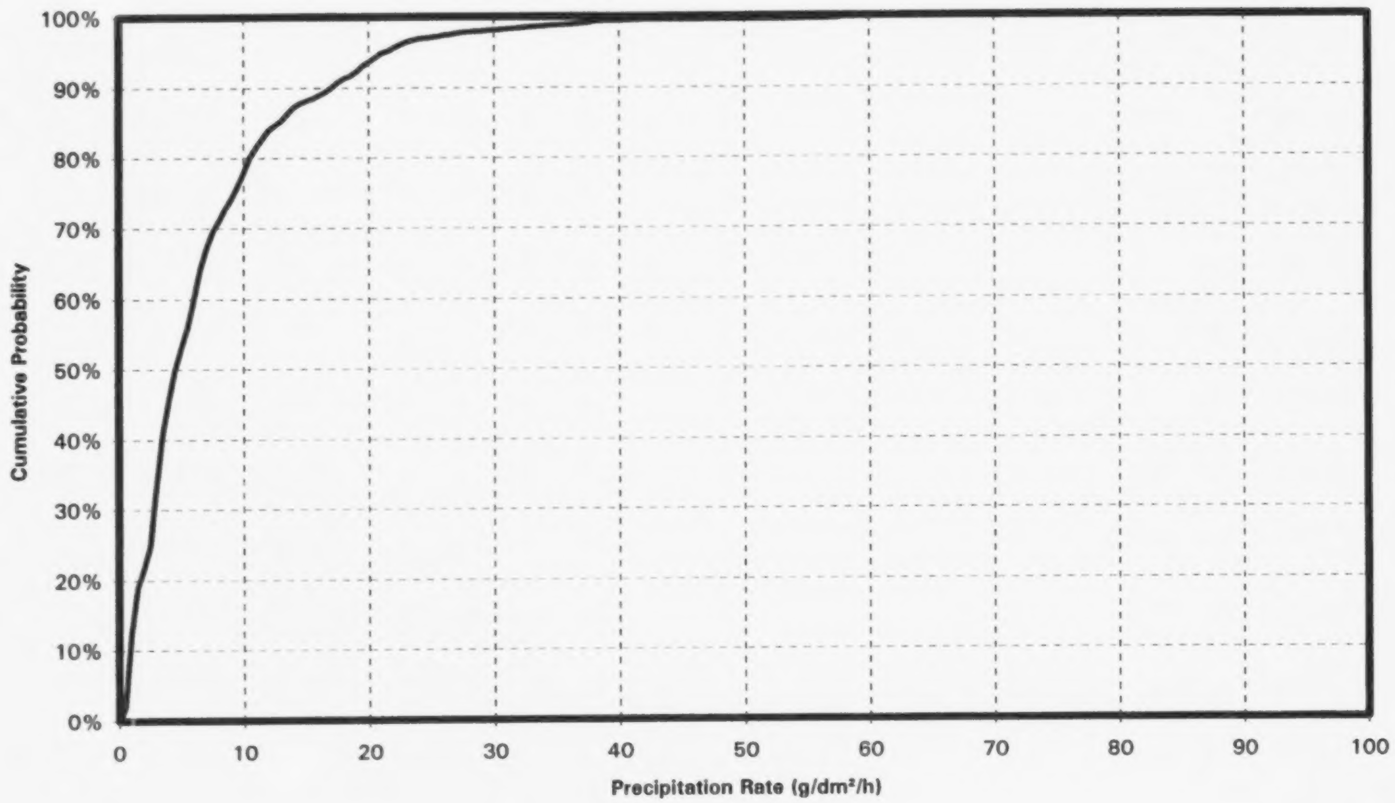
## -7 TO -14°C

## 6-MINUTE RATE EVERY MINUTE

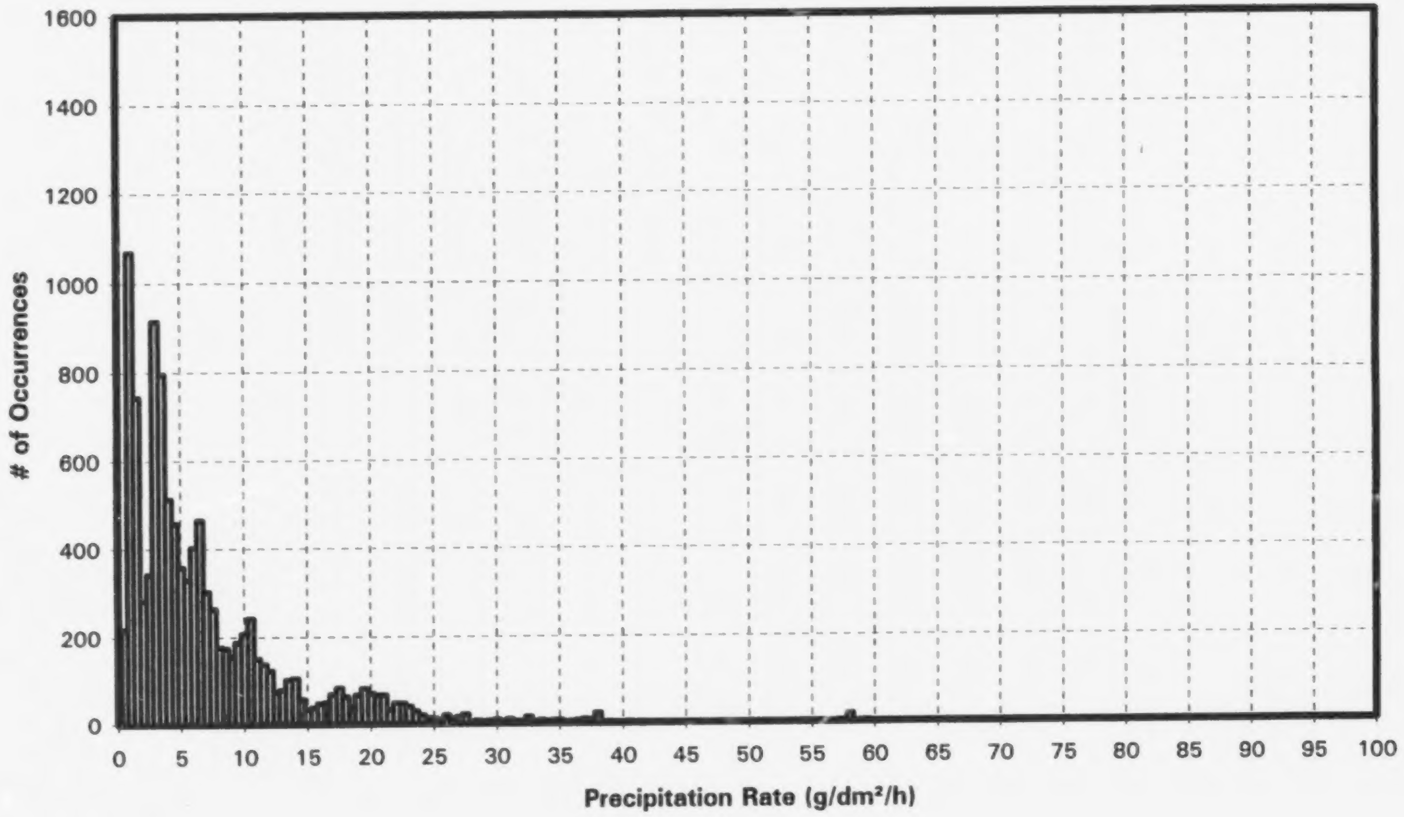
## 1995-2001



## READAC AND CR21X ANALYSIS - NATURAL SNOW
## -14 TO -25°C
## 35-MINUTE RATE EVERY MINUTE
## 1995-2001



## READADC AND CR21X ANALYSIS - NATURAL SNOW
## -14 TO -25°C
## 35-MINUTE RATE EVERY MINUTE
## 1995-2001

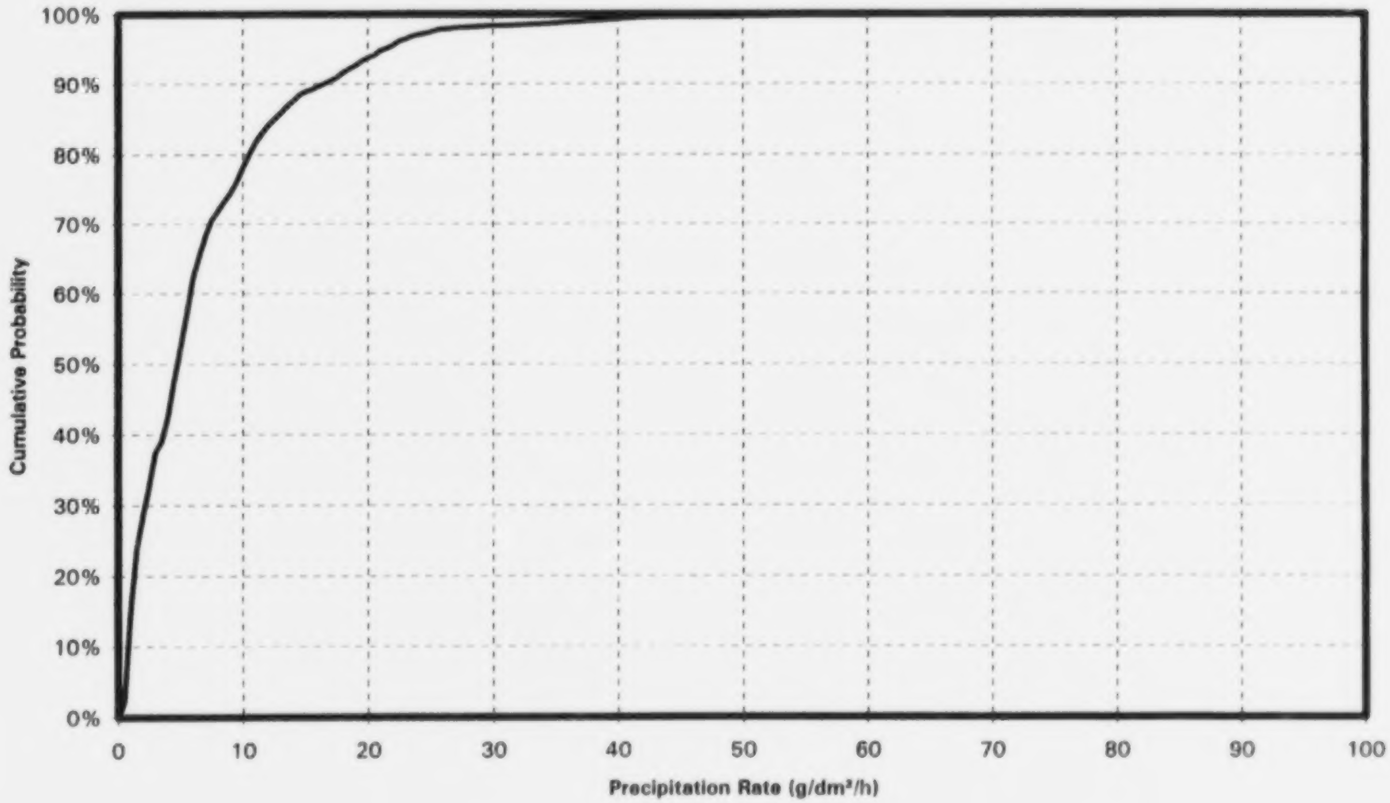


READADC AND CR21X ANALYSIS - NATURAL SNOW

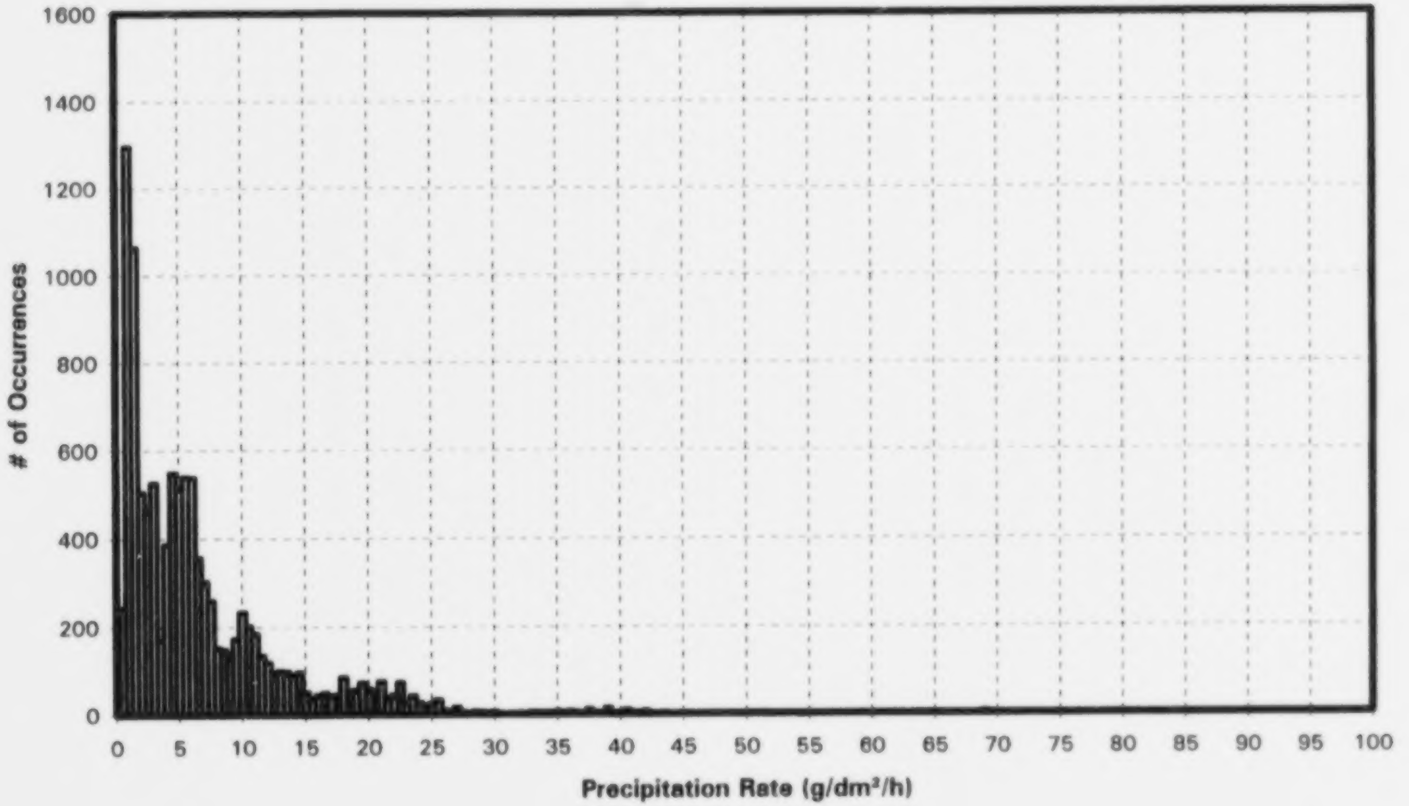
**-14 TO -25°C**

**20-MINUTE RATE EVERY MINUTE**

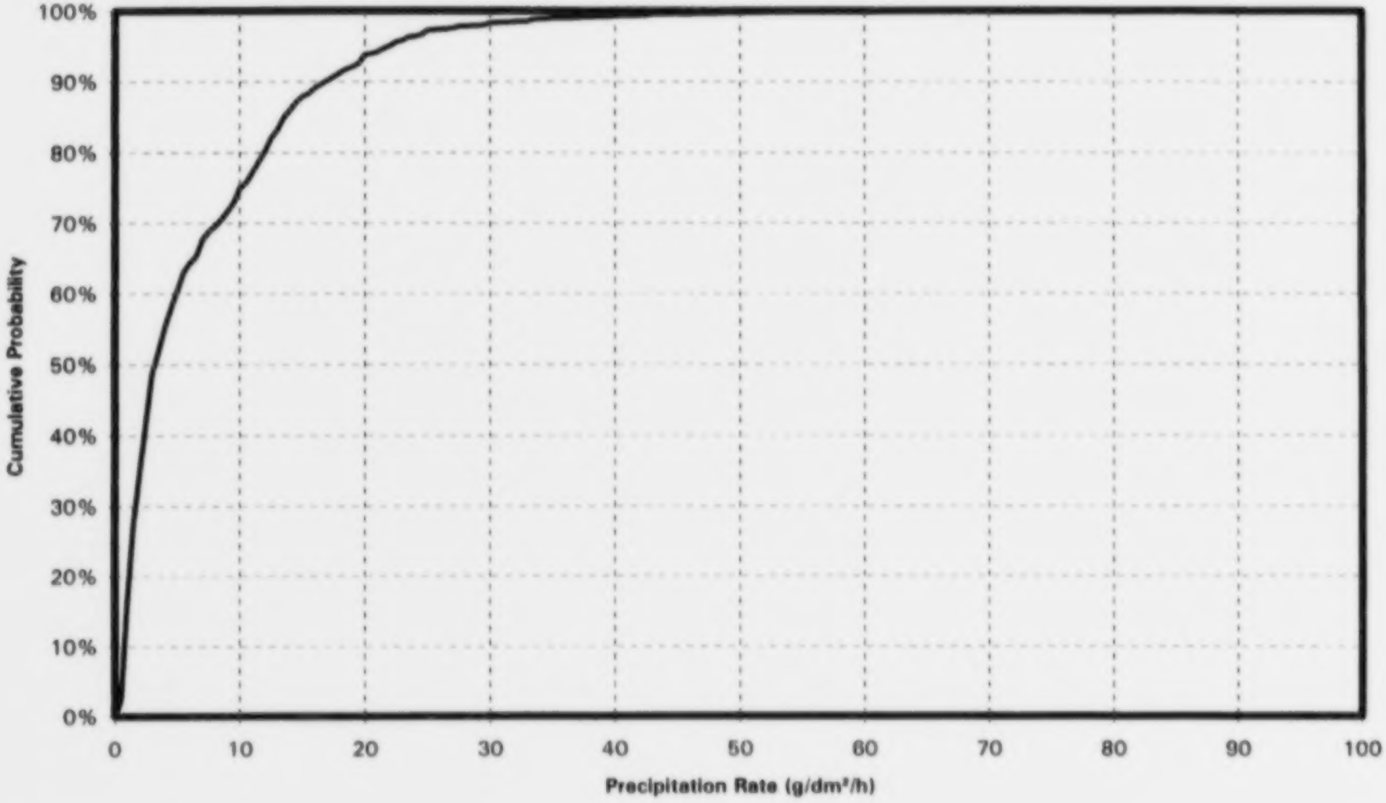
**1995-2001**



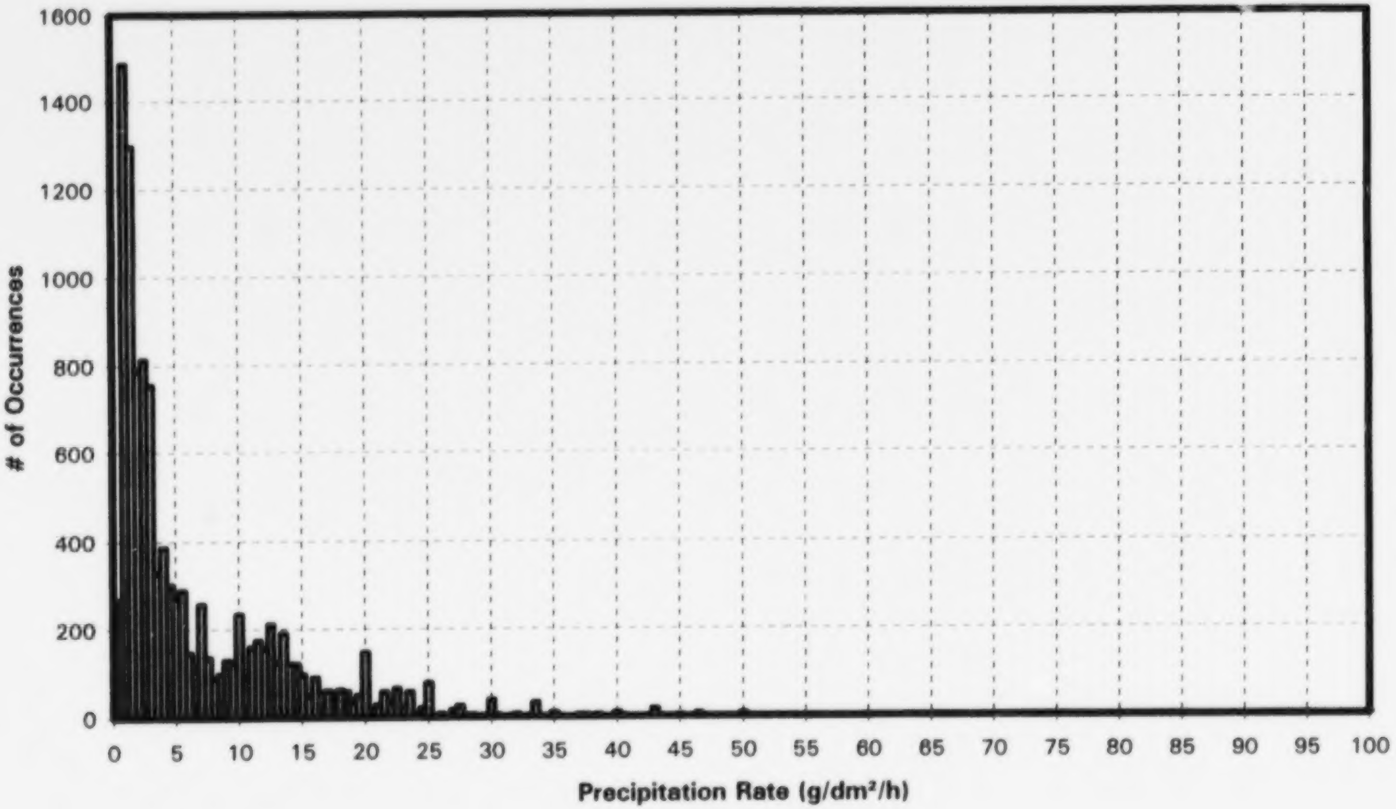
READADAC AND CR21X ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-2001



READADC AND CR21X ANALYSIS - NATURAL SNOW
-14 TO -25°C
**6-MINUTE RATE EVERY MINUTE**
**1995-2001**



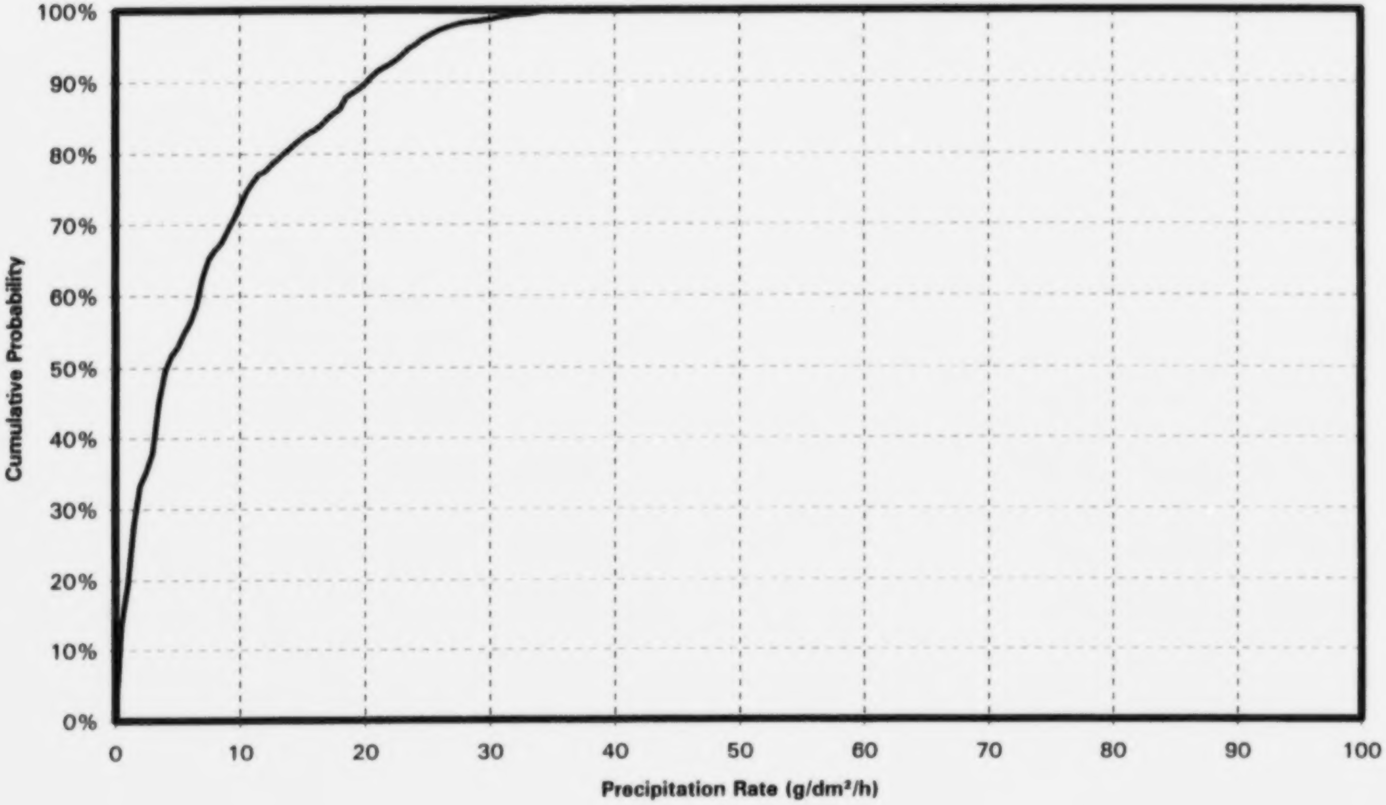
READAC AND CR21X ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-2001



READADAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

**0 TO -3°C**

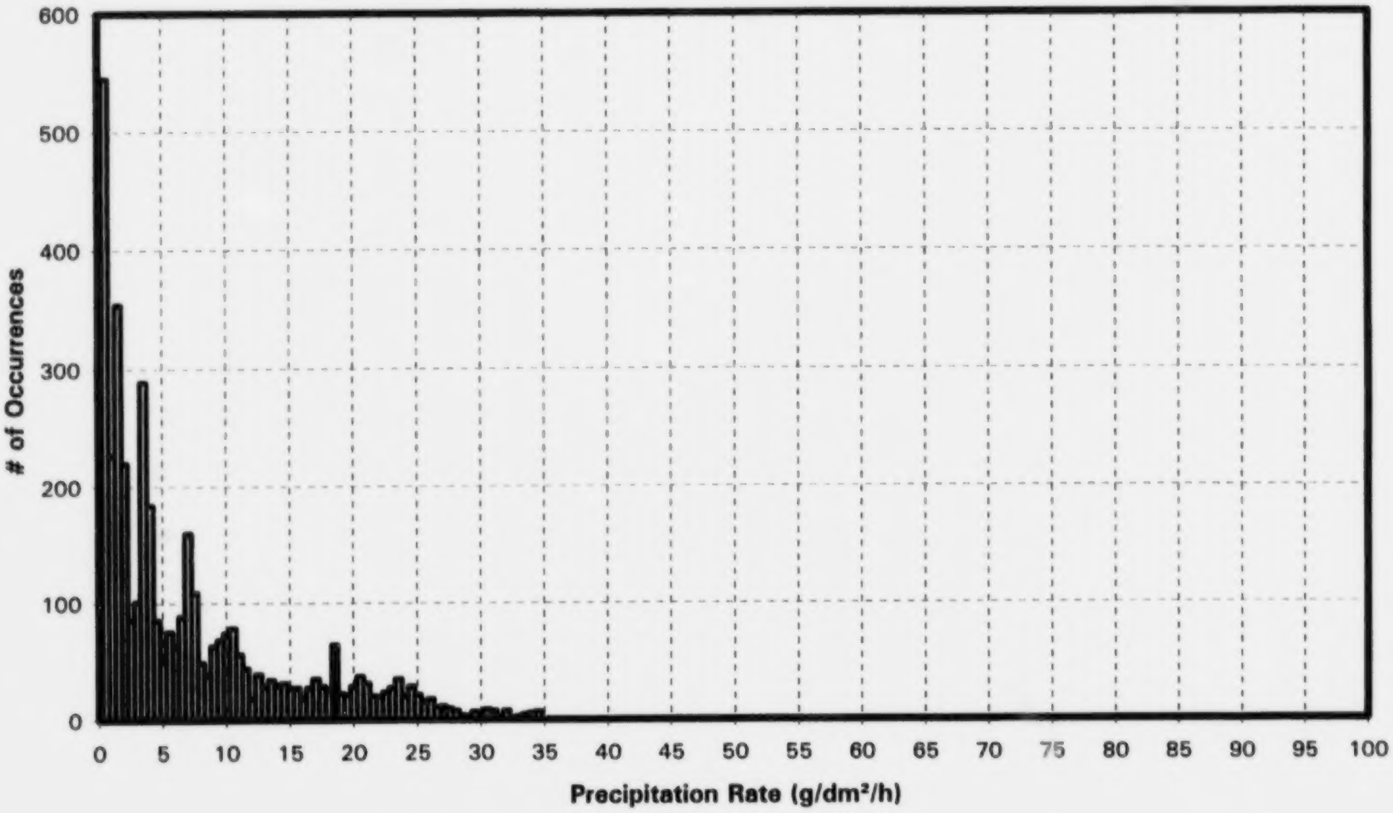
**35-MINUTE RATE EVERY MINUTE**



## READADC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

### 0 TO -3°C

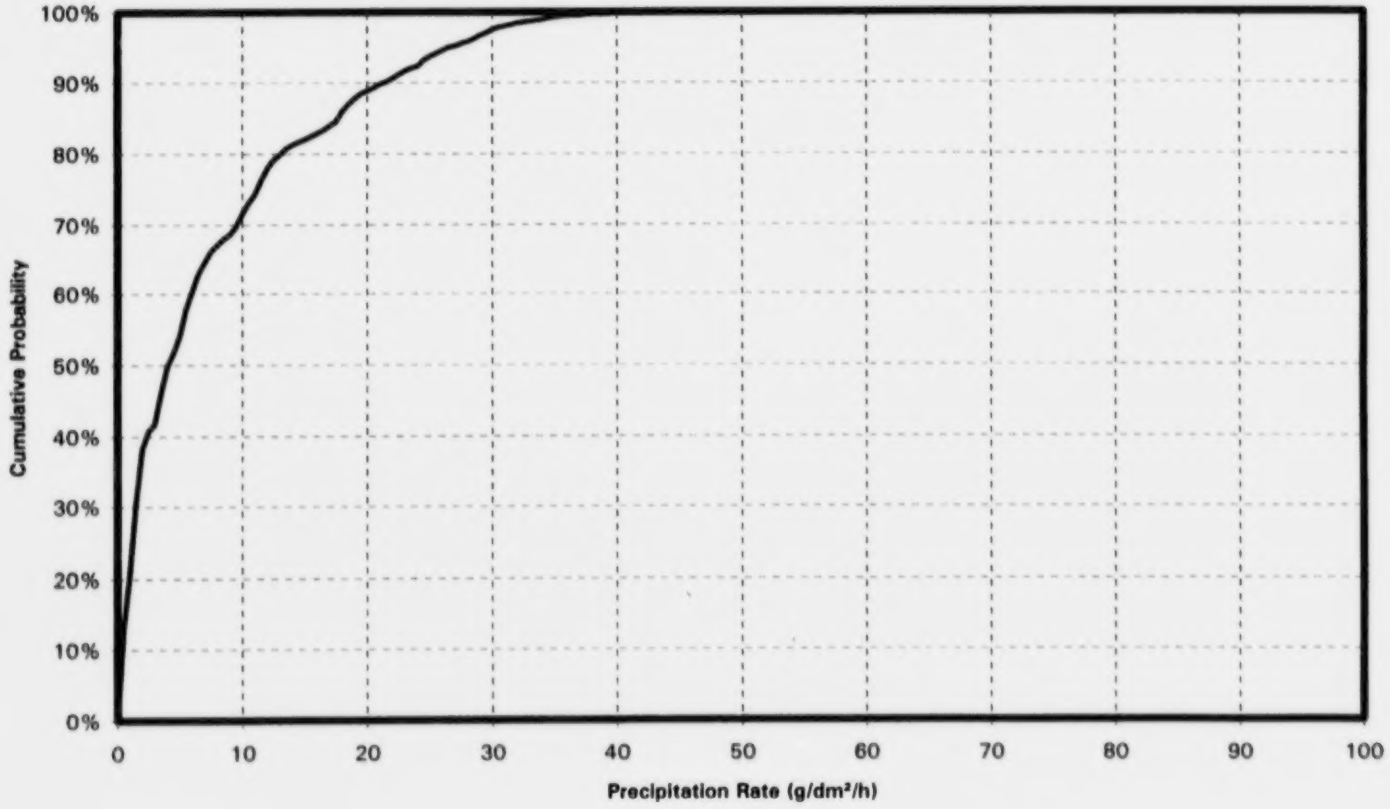
### 35-MINUTE RATE EVERY MINUTE



## READADAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

## 0 TO -3°C

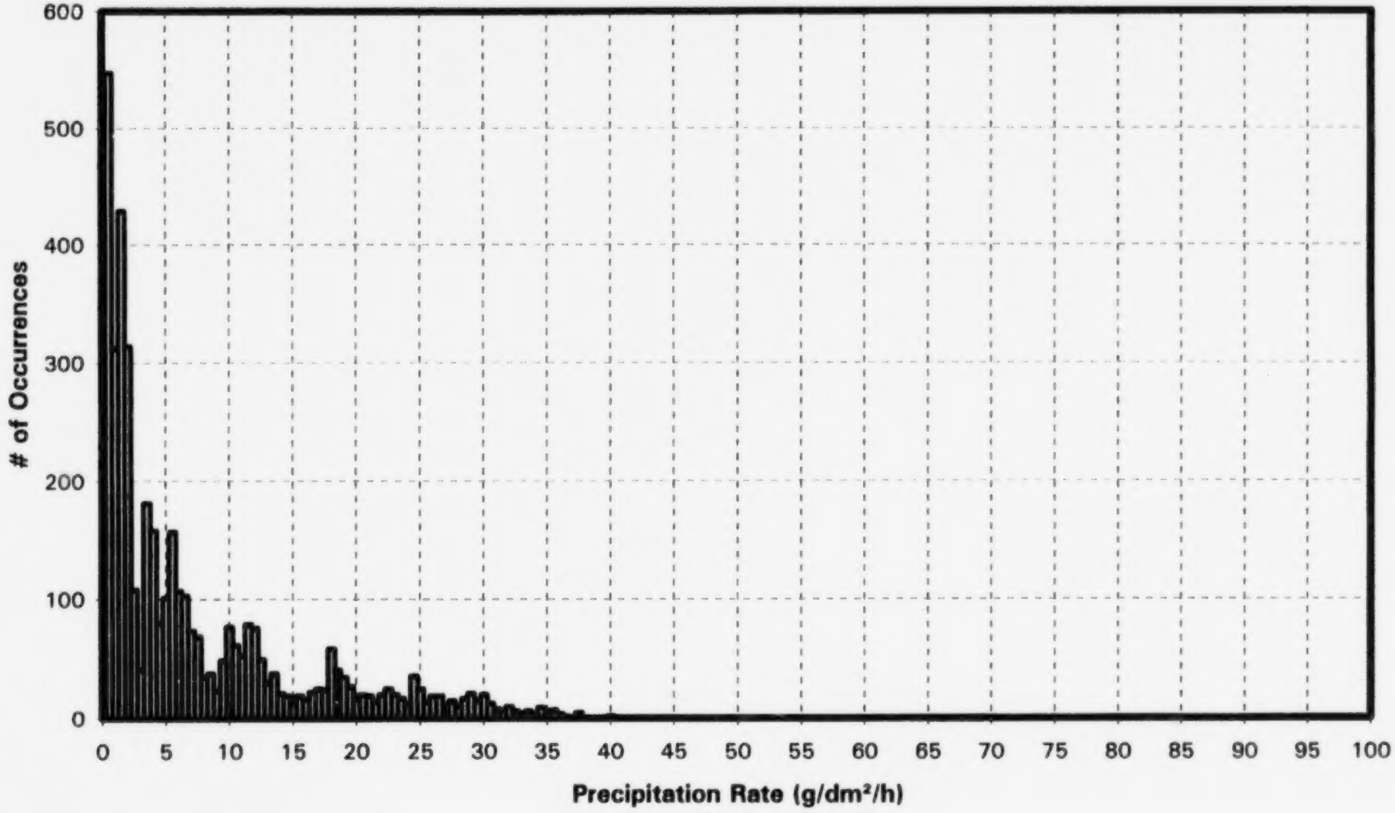
### 20-MINUTE RATE EVERY MINUTE

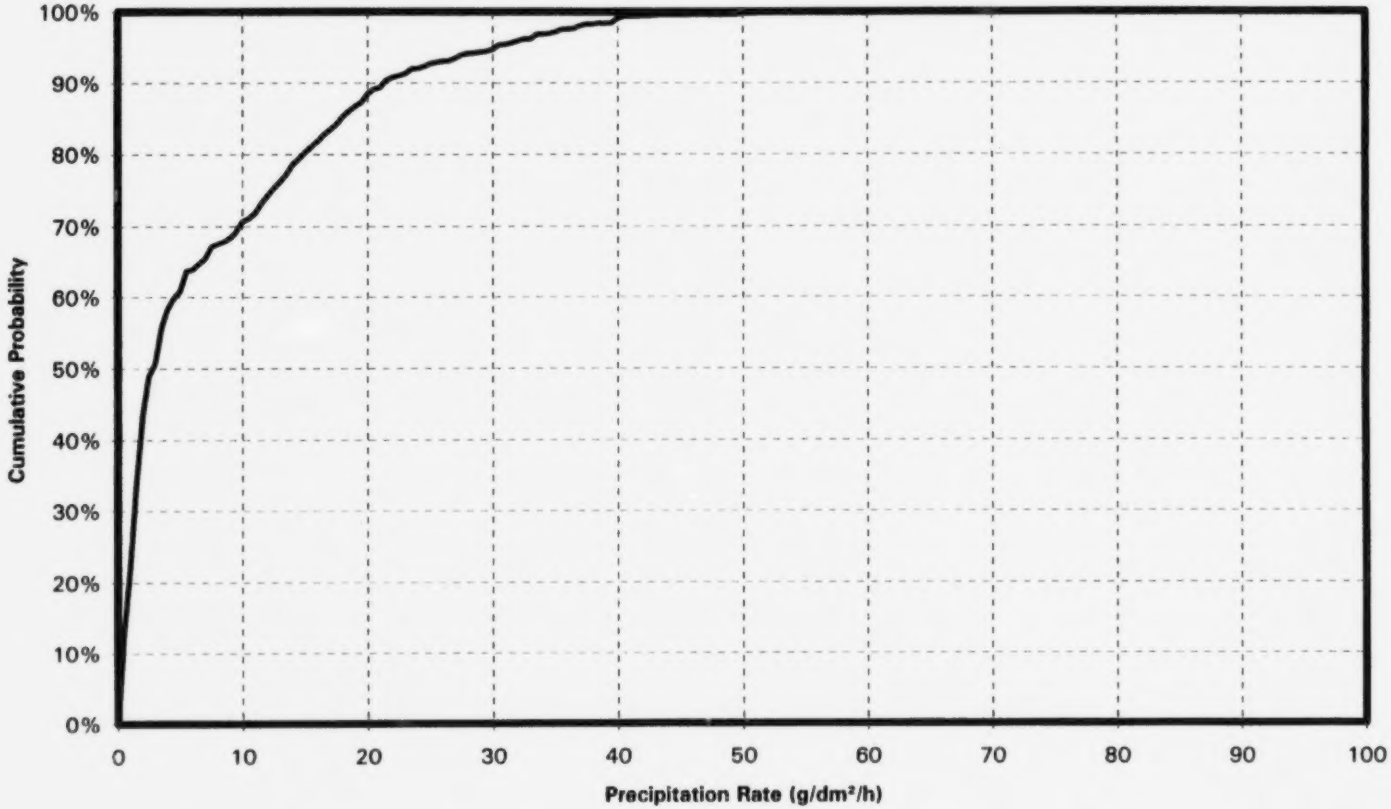


## READAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

## 0 TO -3°C

### 20-MINUTE RATE EVERY MINUTE





READAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

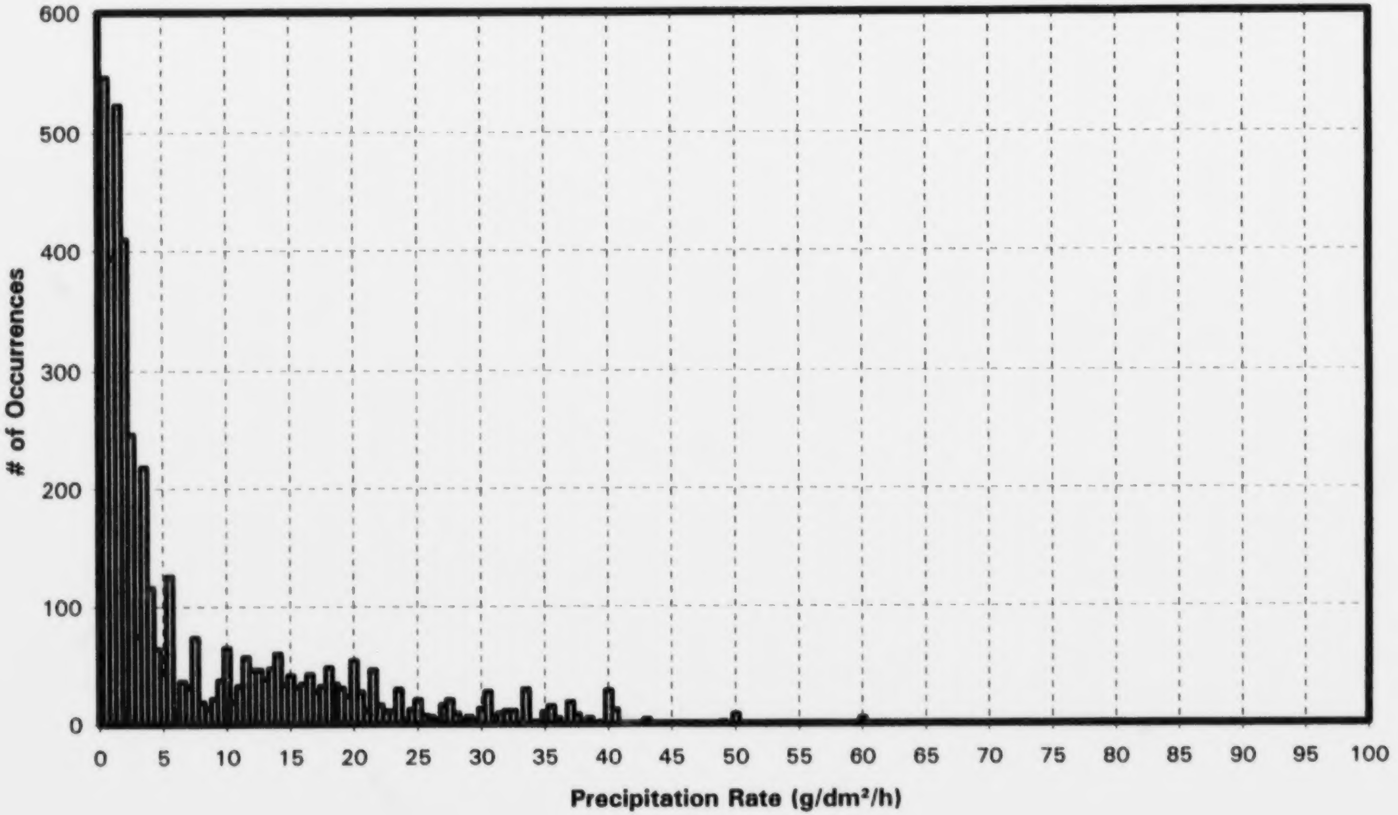
**0 TO -3°C**

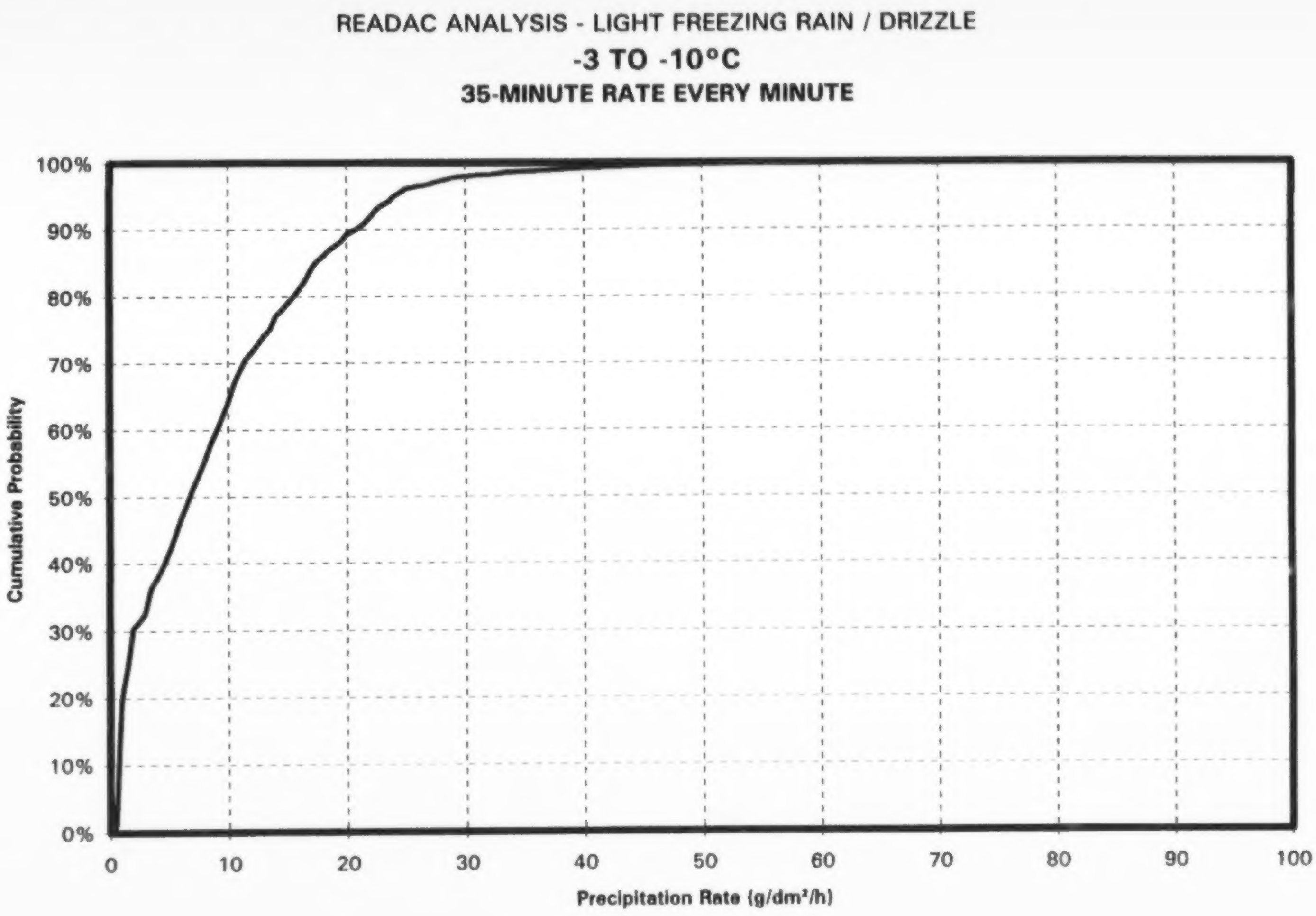
**6-MINUTE RATE EVERY MINUTE**

## READAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

### 0 TO -3°C

### 6-MINUTE RATE EVERY MINUTE



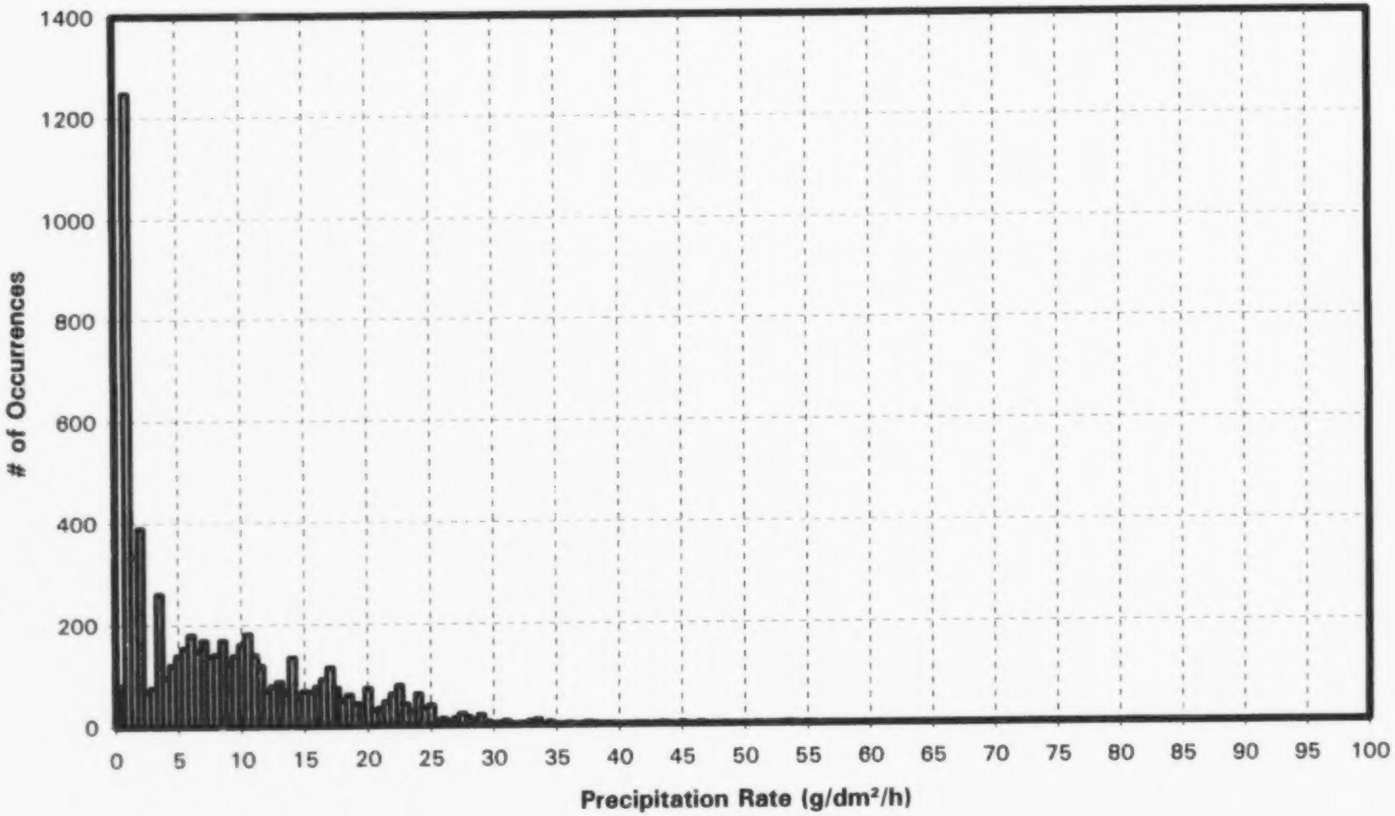


READADAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE

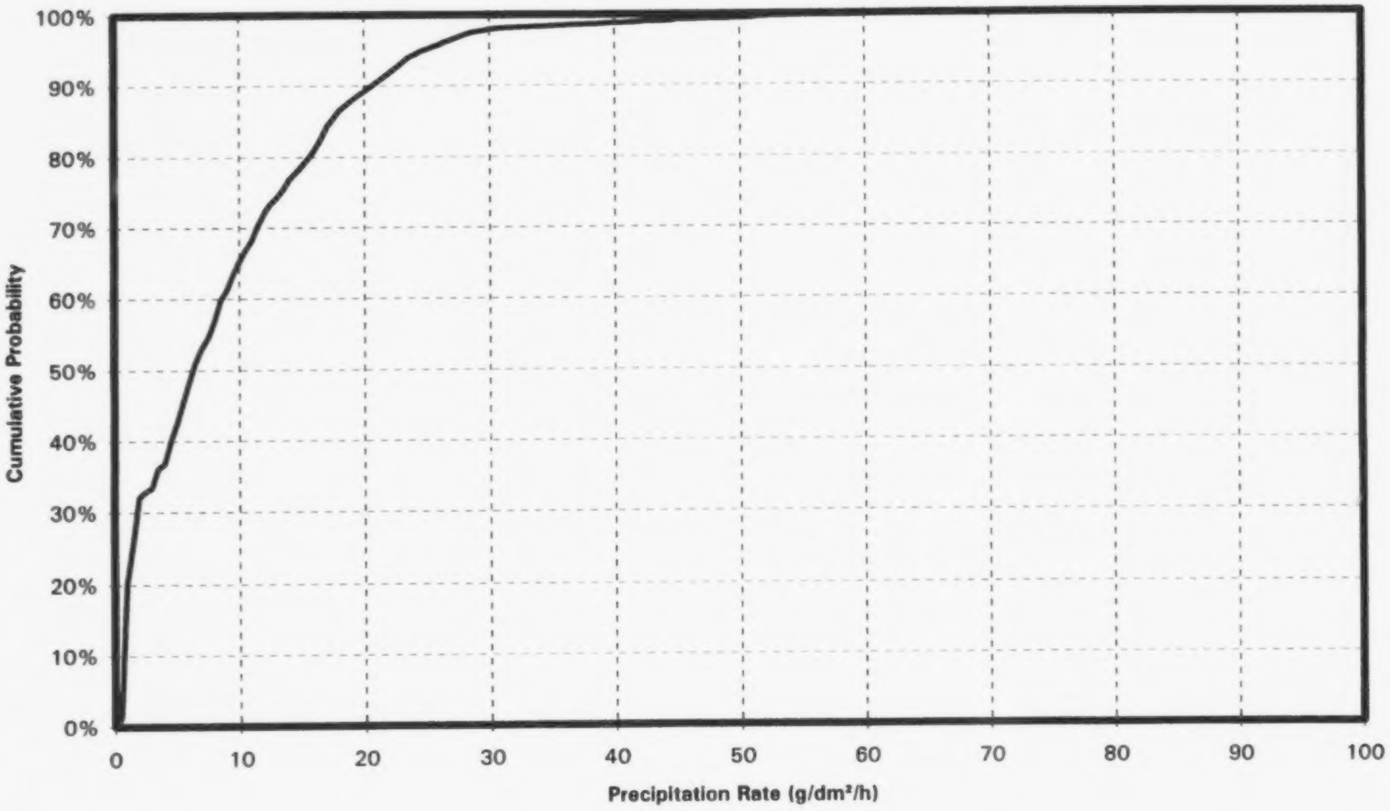
## READADC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

## -3 TO -10°C

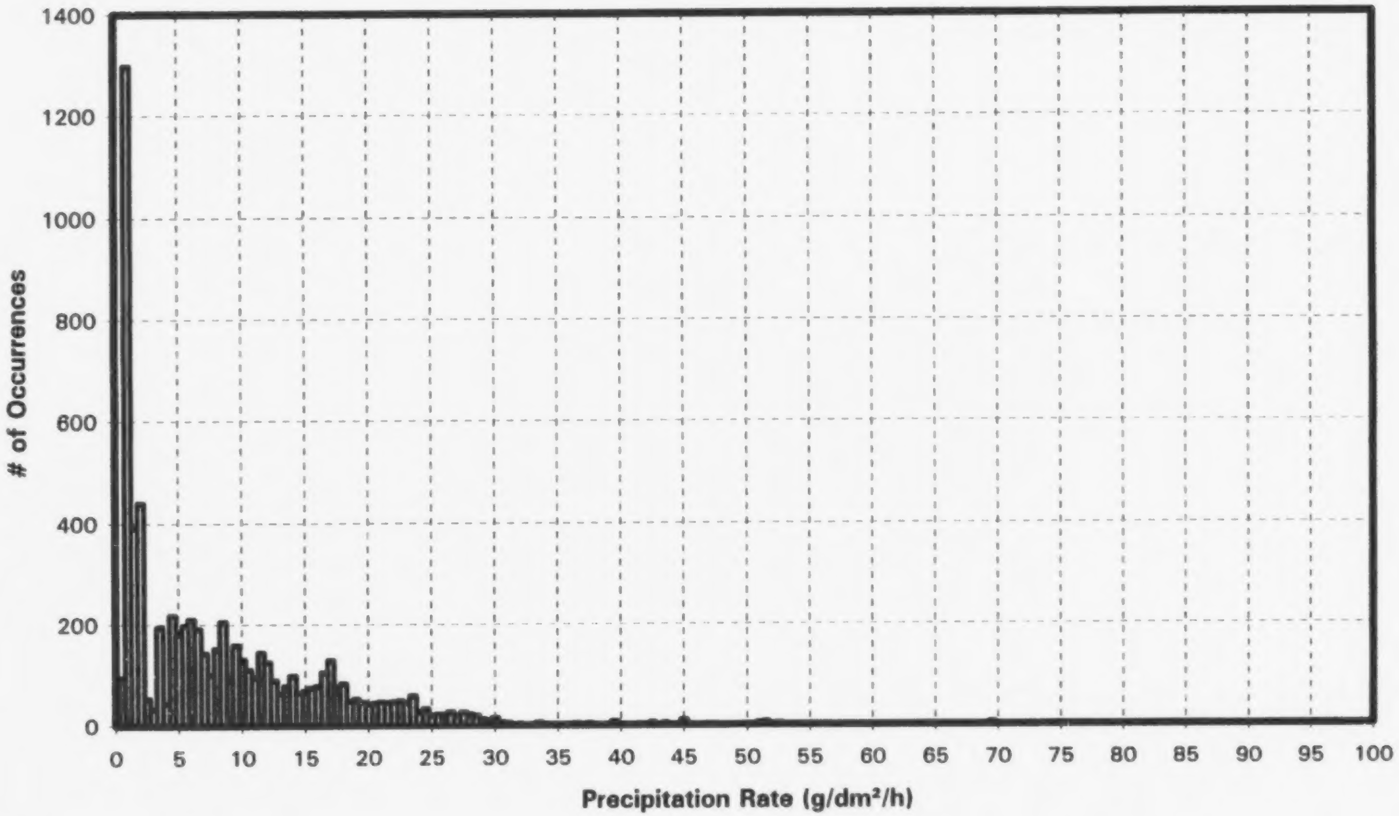
### 35-MINUTE RATE EVERY MINUTE



## READAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
## -3 TO -10°C
### 20-MINUTE RATE EVERY MINUTE



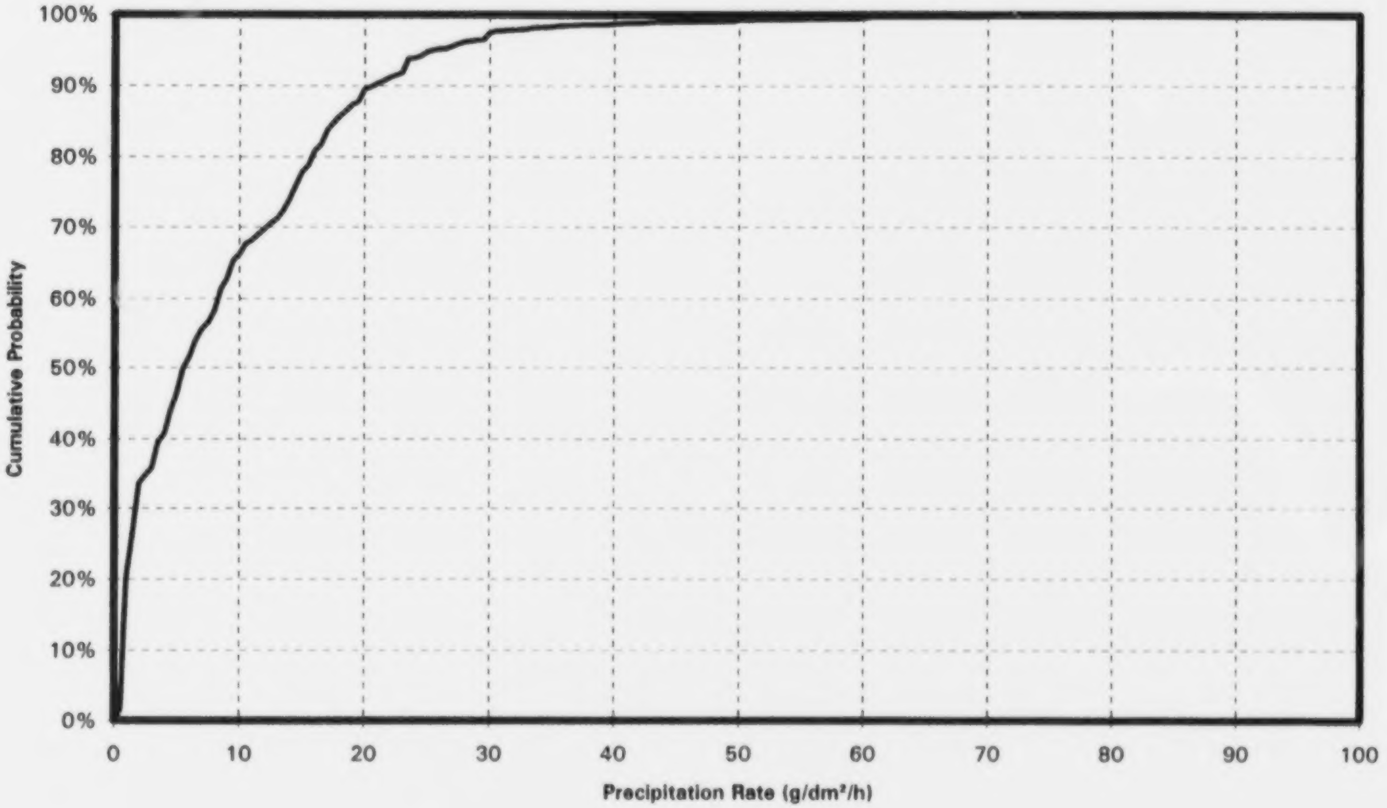
## READADC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
### -3 TO -10°C
### 20-MINUTE RATE EVERY MINUTE



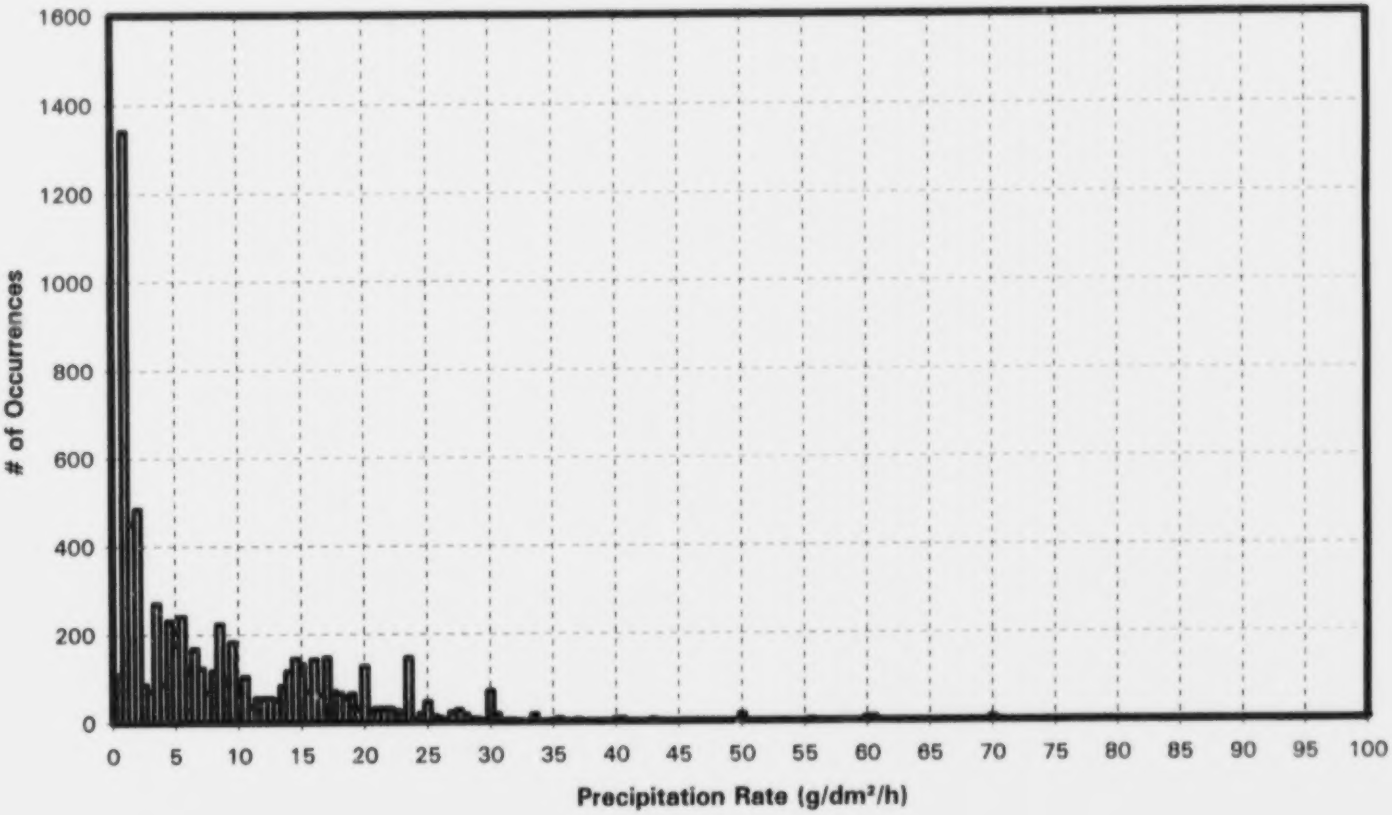
## READADC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE

### -3 TO -10°C

### 6-MINUTE RATE EVERY MINUTE



## READAC ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
## -3 TO -10°C
### 6-MINUTE RATE EVERY MINUTE

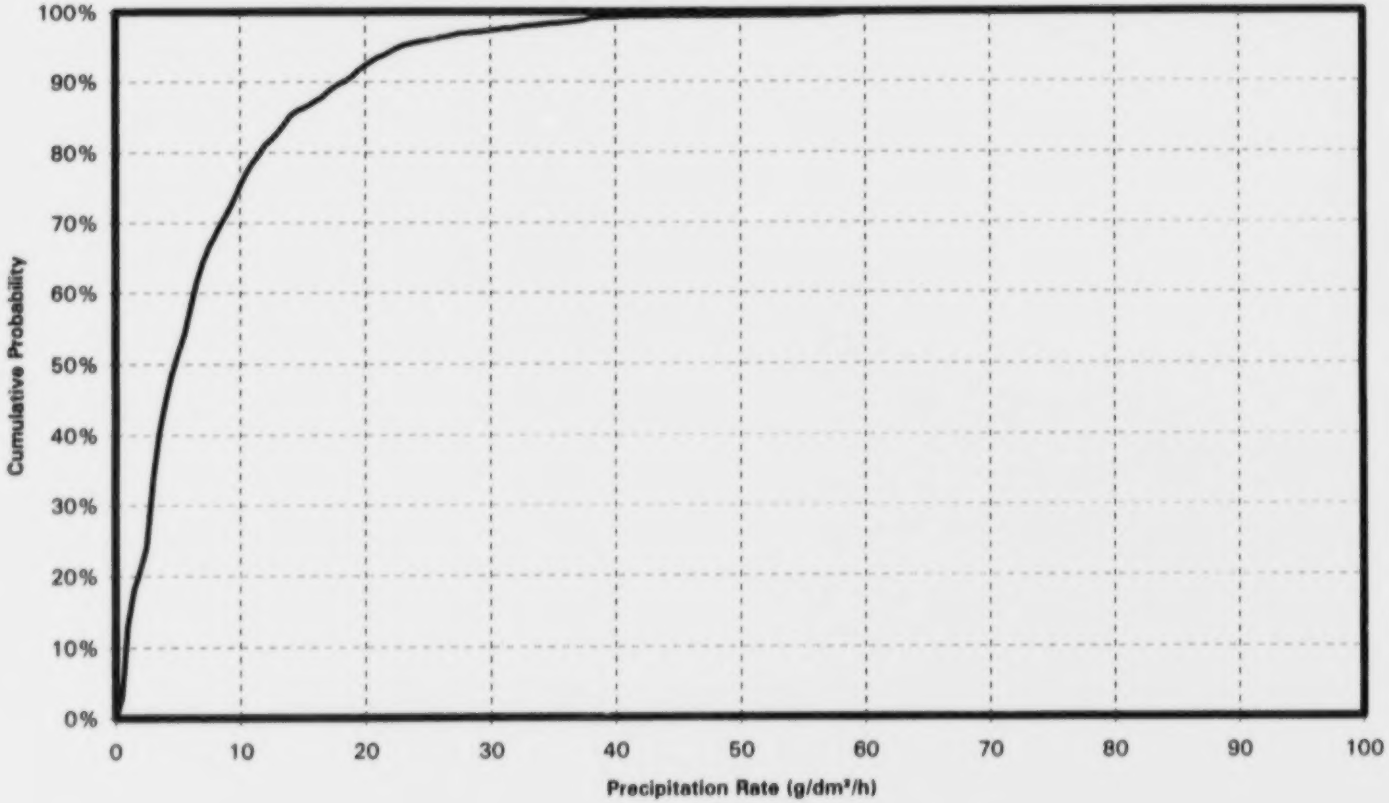


## READADC AND CR21X ANALYSIS - NATURAL SNOW

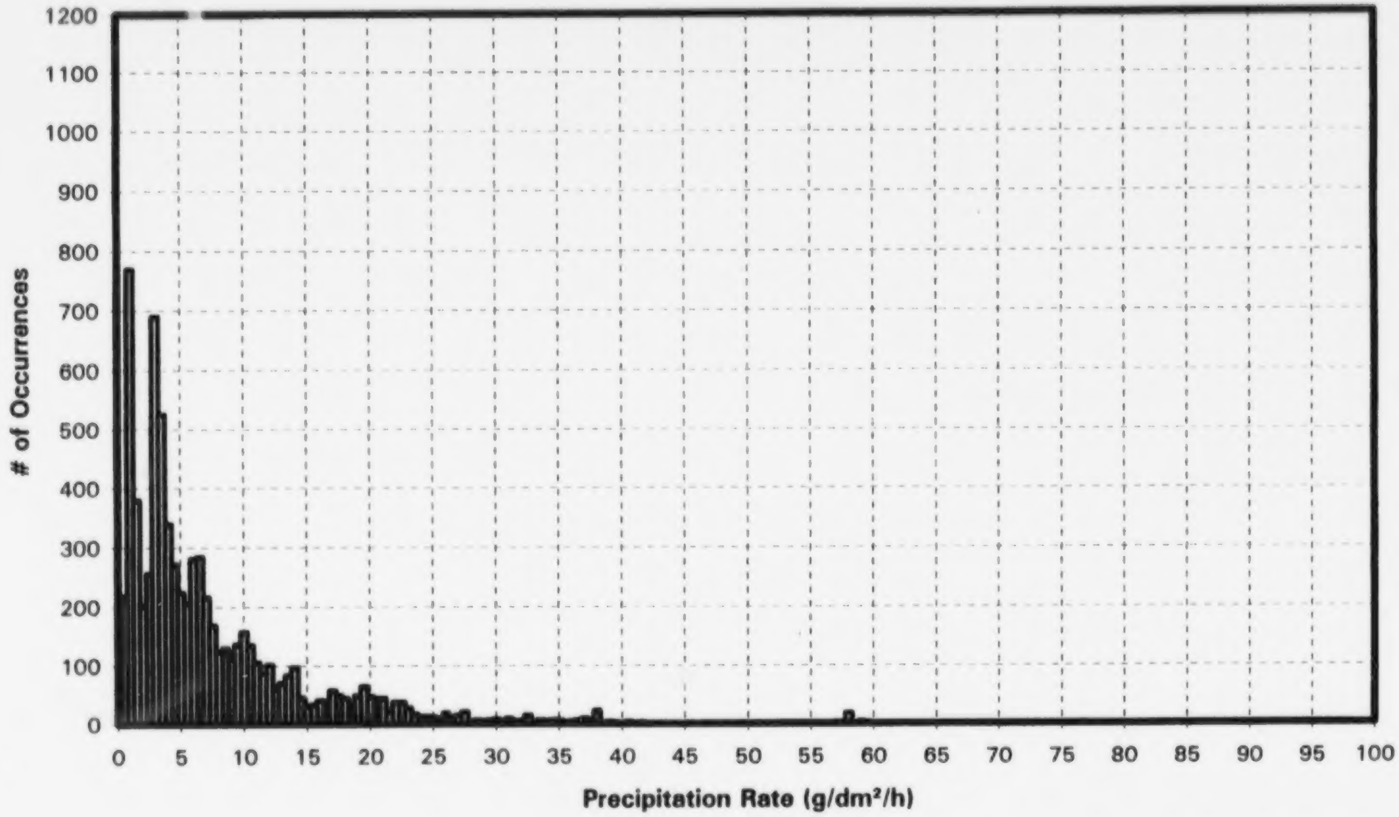
## -14 TO -18°C

### 35-MINUTE RATE EVERY MINUTE

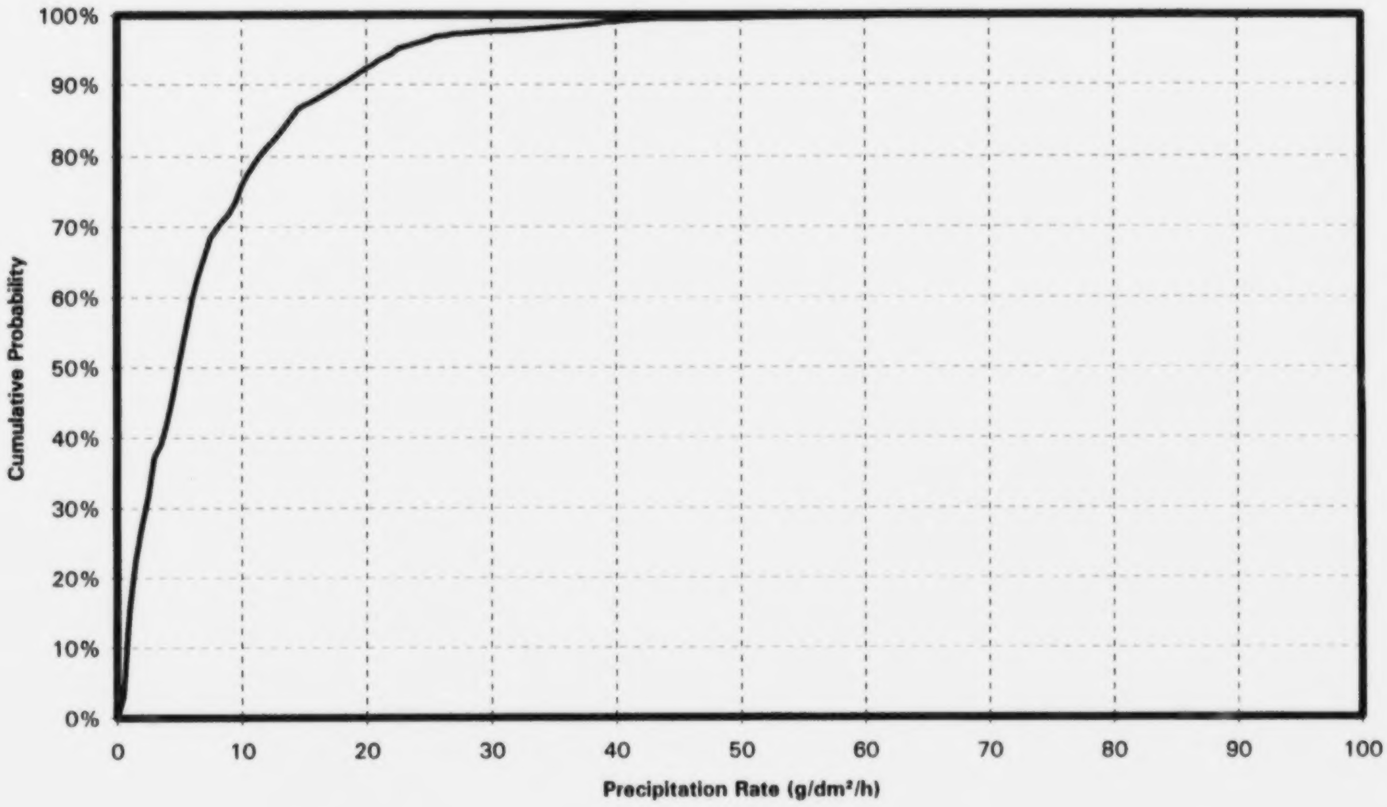
### 1995-2001



READADC AND CR21X ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-2001



## READADAC AND CR21X ANALYSIS - NATURAL SNOW
## -14 TO -18°C
### 20-MINUTE RATE EVERY MINUTE
### 1995-2001

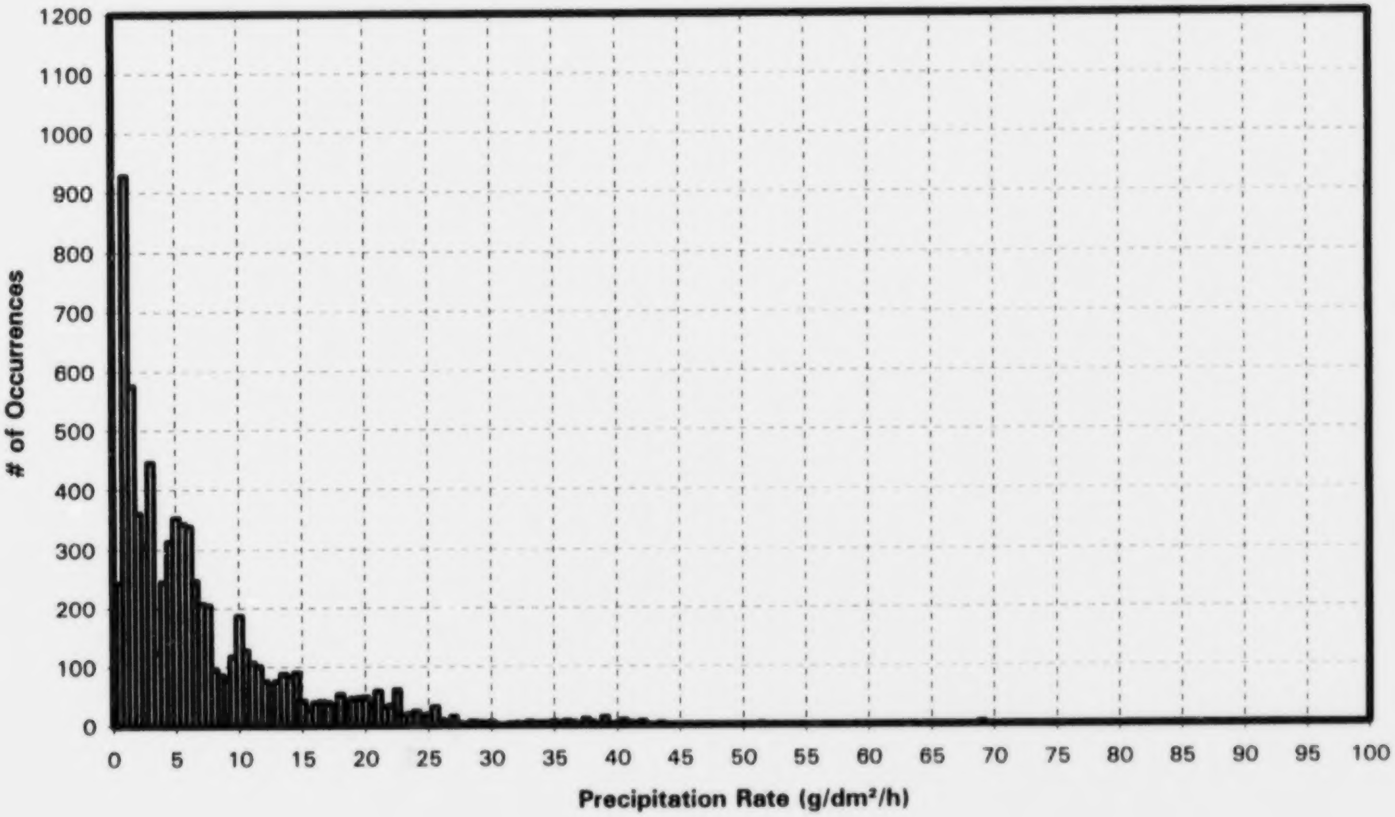


## READAC AND CR21X ANALYSIS - NATURAL SNOW

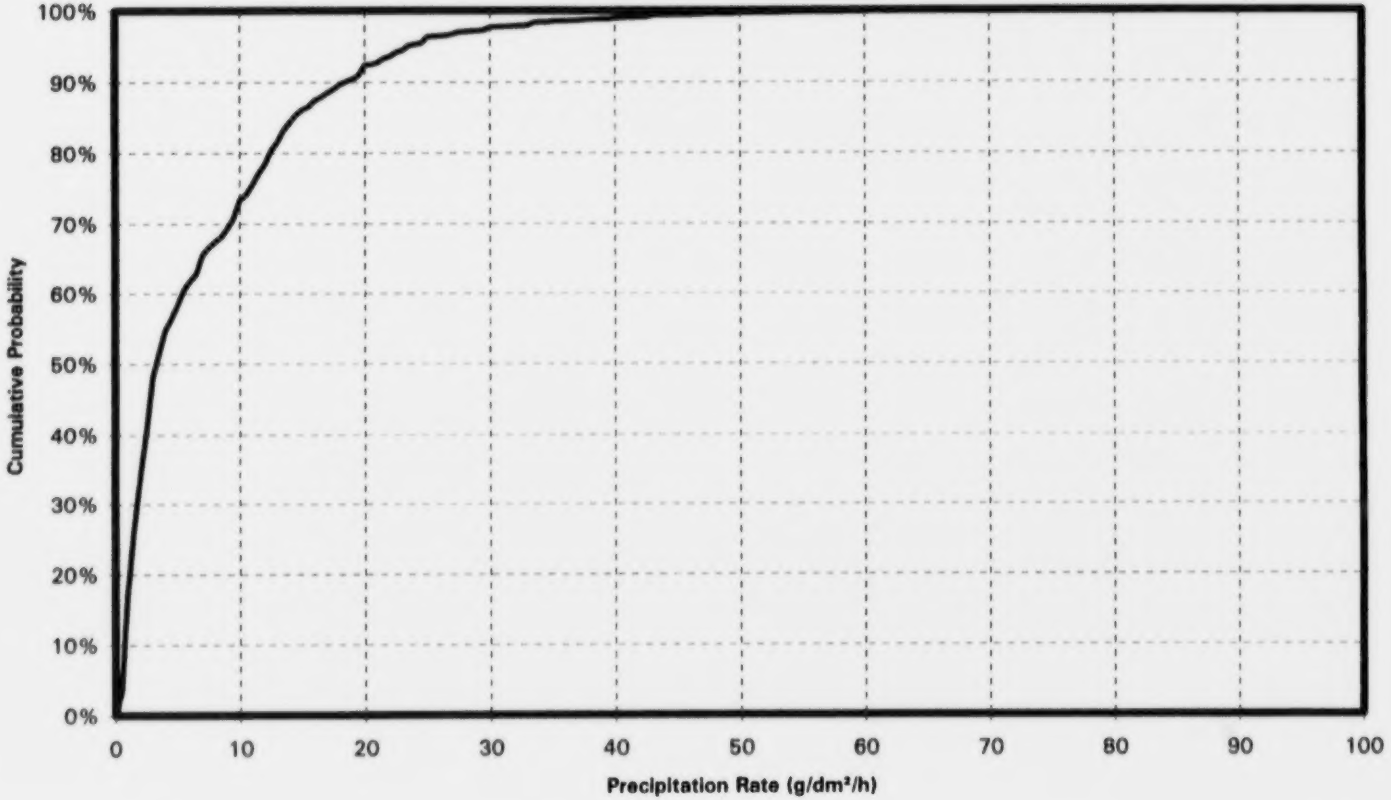
### -14 TO -18°C

### 20-MINUTE RATE EVERY MINUTE

### 1995-2001



## READAC AND CR21X ANALYSIS - NATURAL SNOW
## -14 TO -18°C
## 6-MINUTE RATE EVERY MINUTE
## 1995-2001

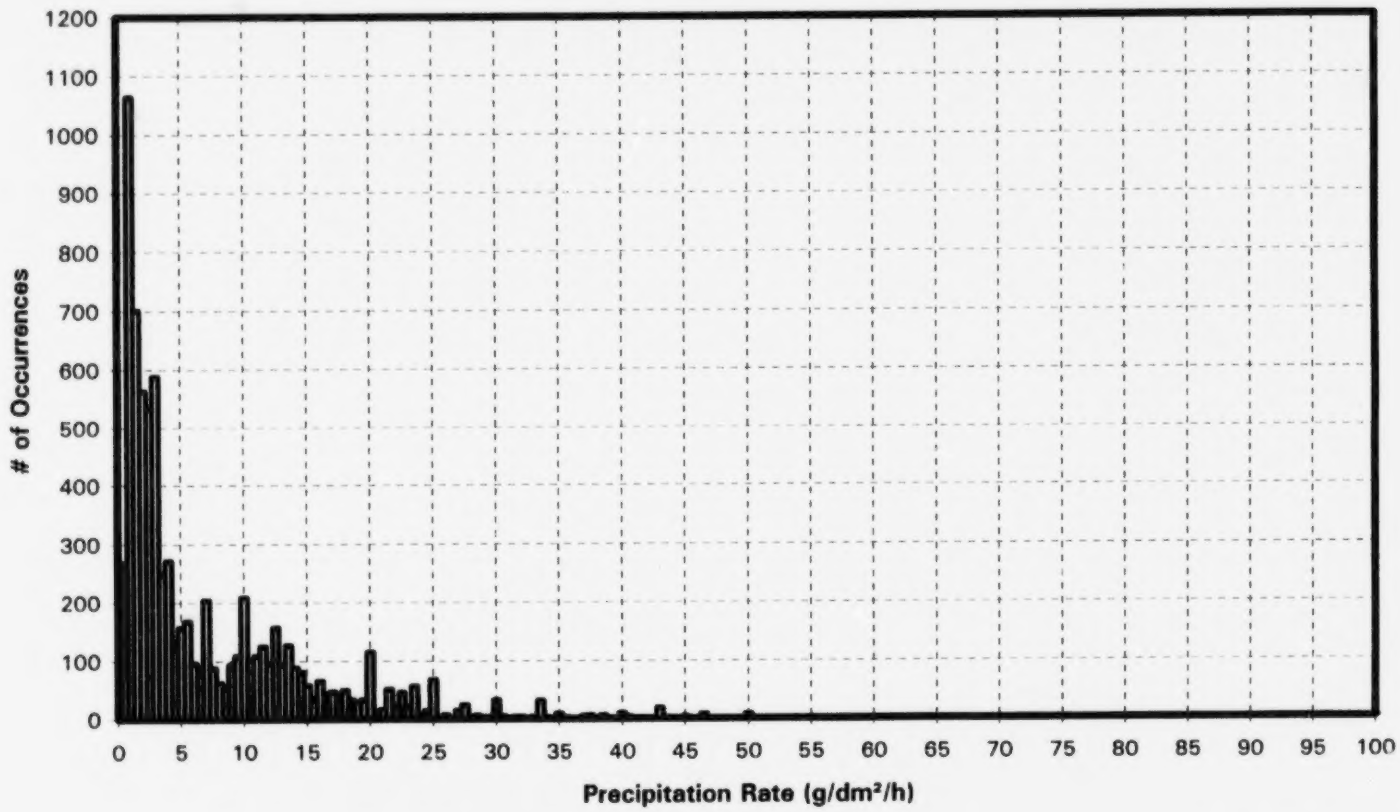


## READADC AND CR21X ANALYSIS - NATURAL SNOW

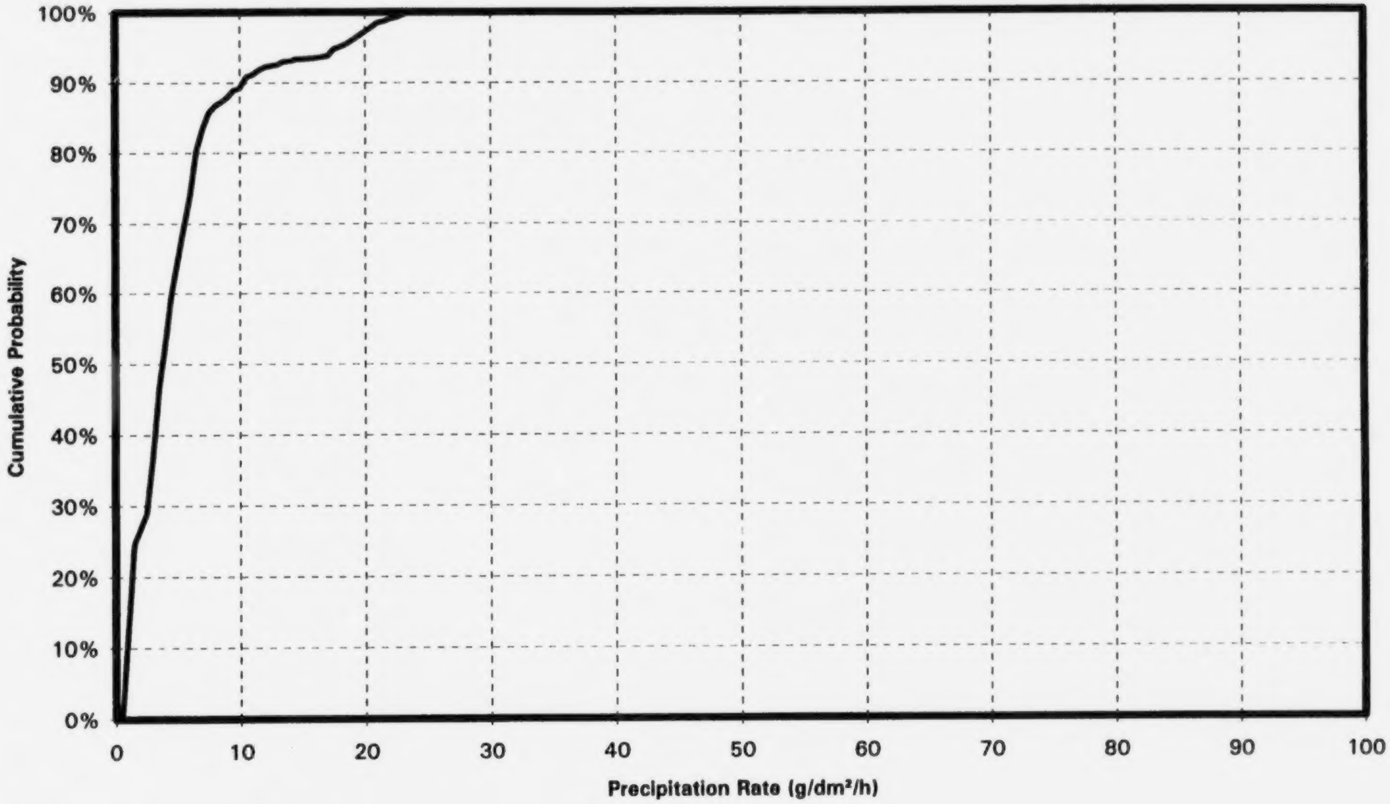
## -14 TO -18°C

## 6-MINUTE RATE EVERY MINUTE

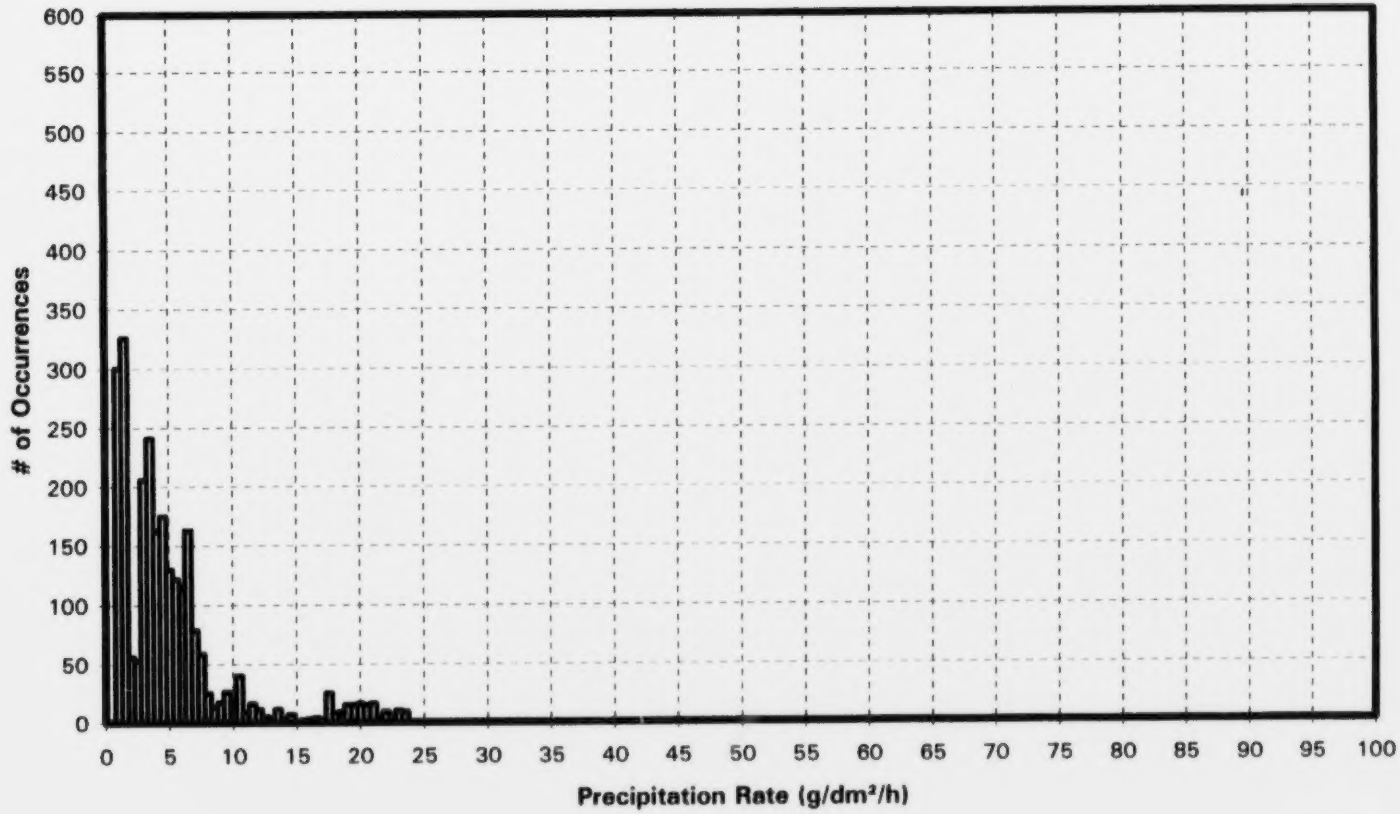
## 1995-2001



READADC AND CR21X ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-2001



## READADC AND CR21X ANALYSIS - NATURAL SNOW
## -18 TO -22°C
### 35-MINUTE RATE EVERY MINUTE
### 1995-2001



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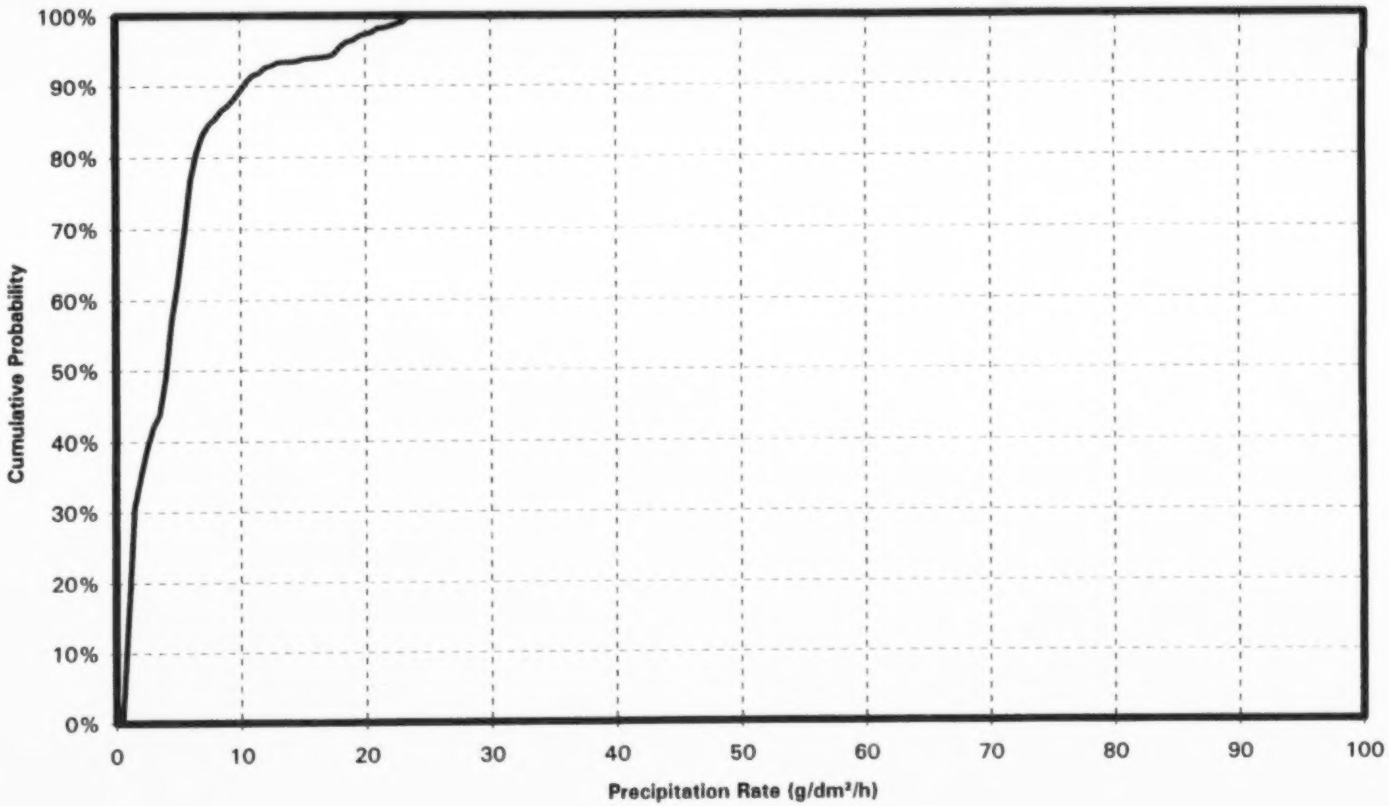
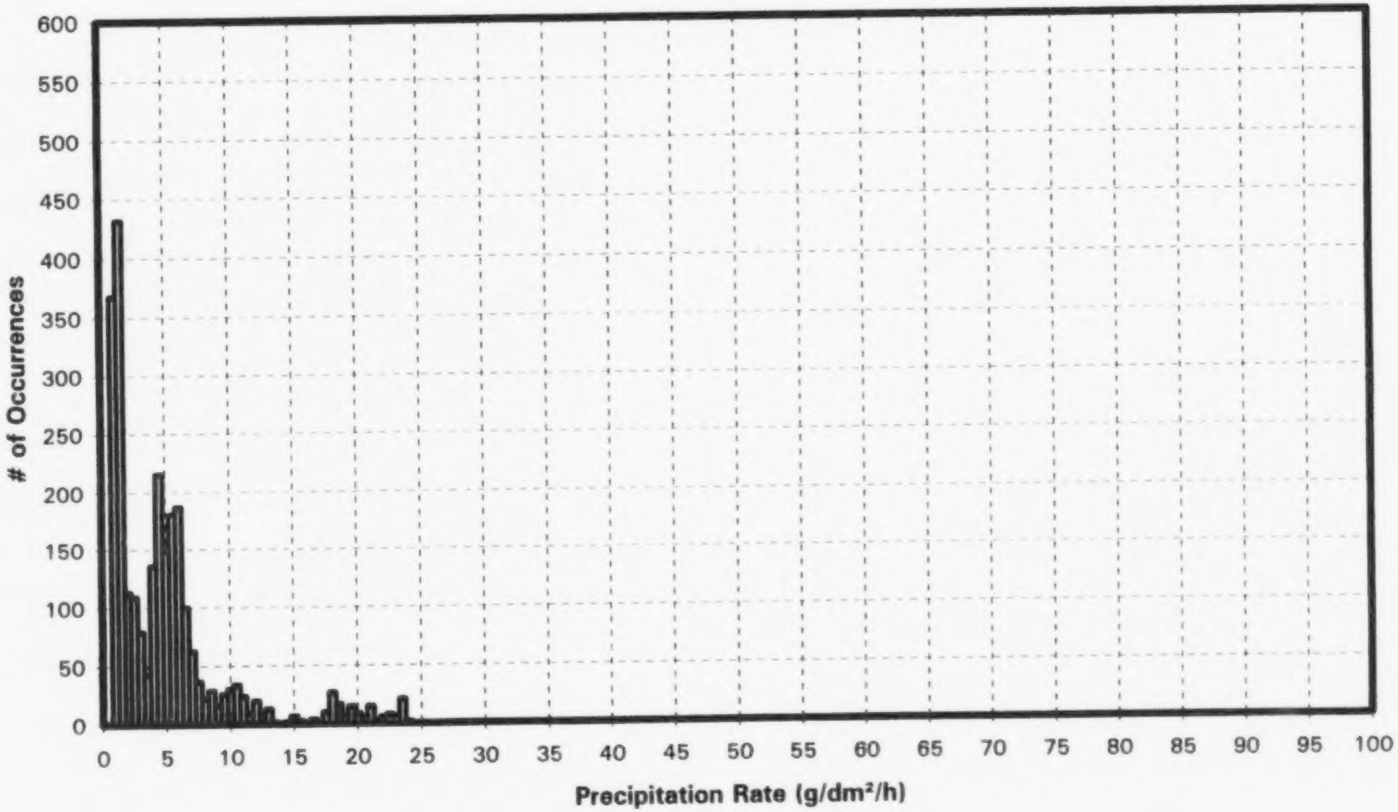
## -18 TO -22°C

## 20-MINUTE RATE EVERY MINUTE

## 1995-2001



## READAC AND CR21X ANALYSIS - NATURAL SNOW
## -18 TO -22°C
## 20-MINUTE RATE EVERY MINUTE
## 1995-2001

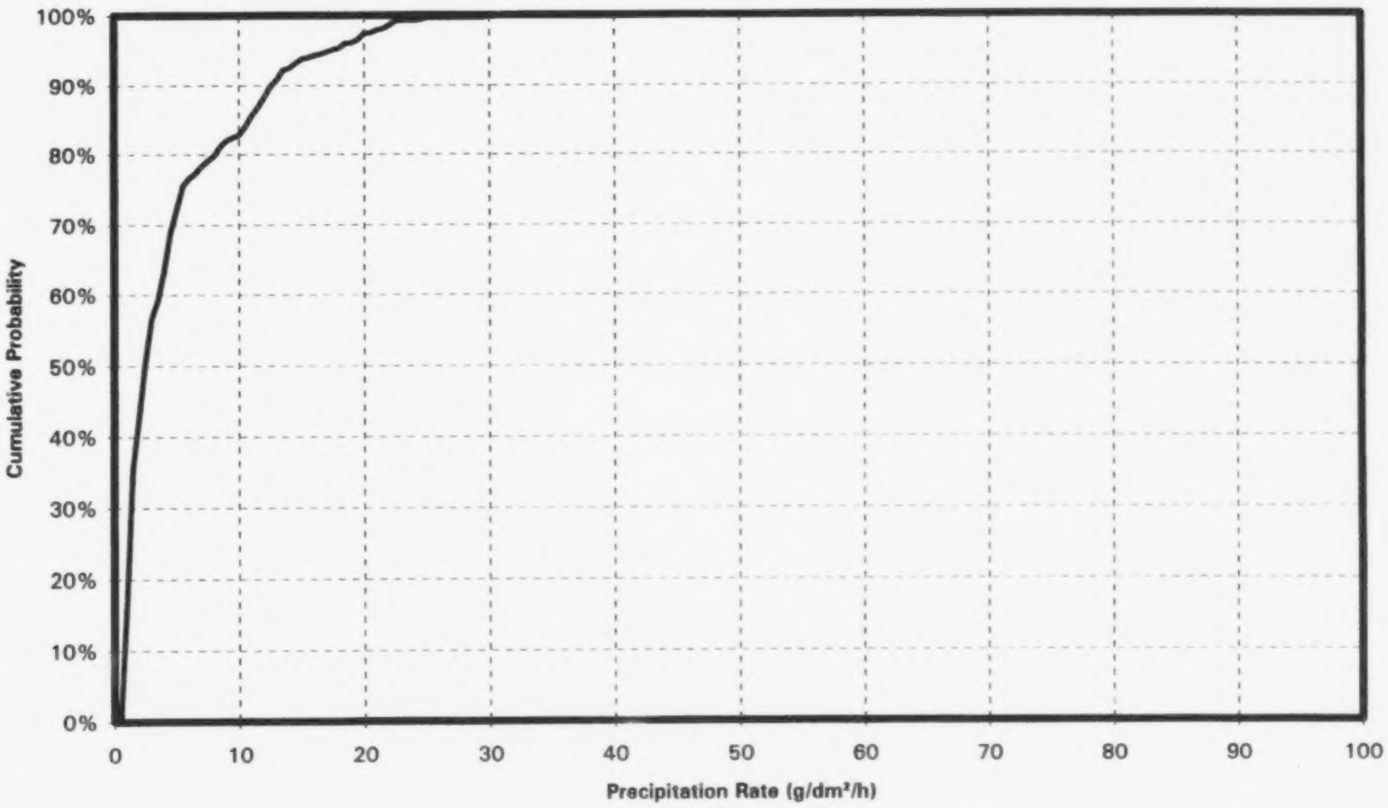


READADC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

6-MINUTE RATE EVERY MINUTE

1995-2001

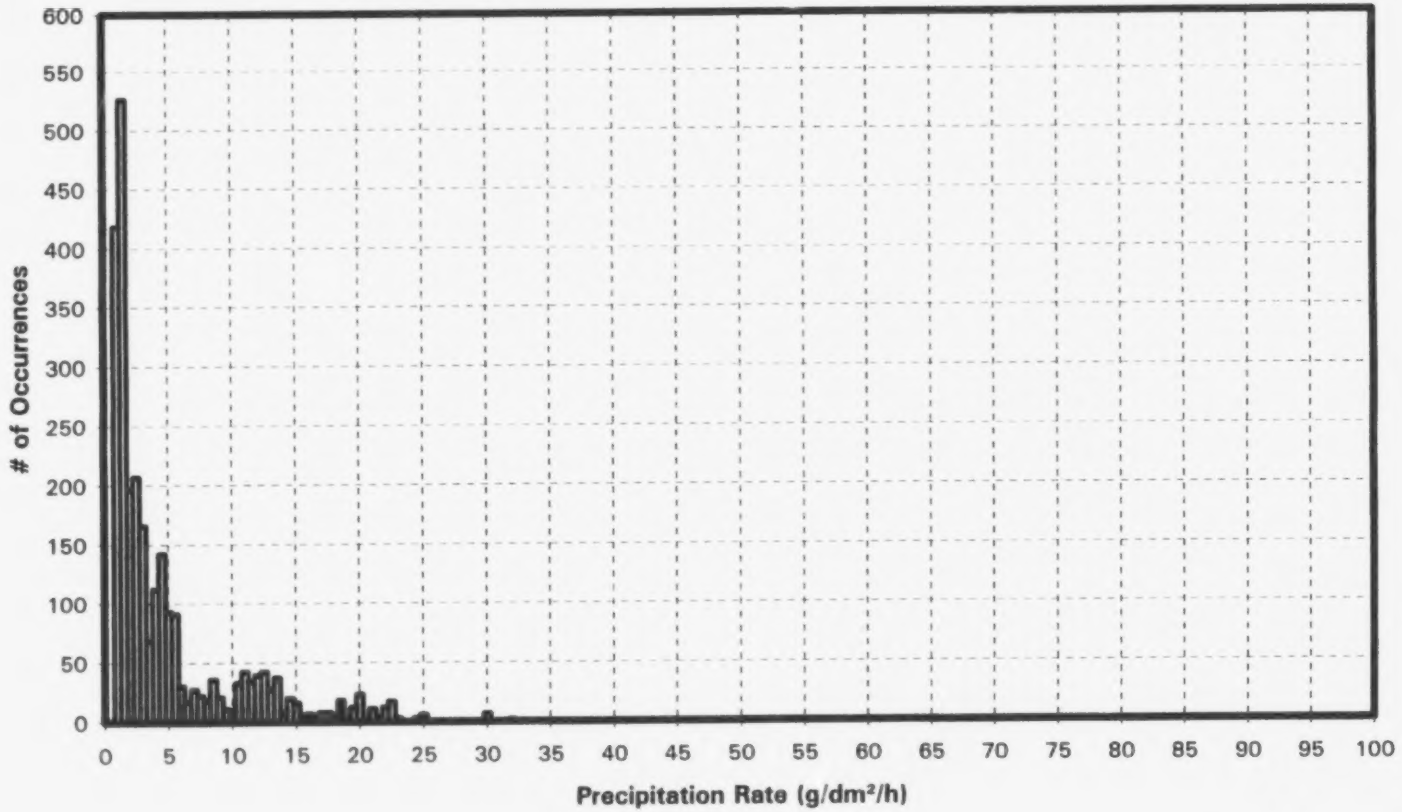


READADAC AND CR21X ANALYSIS - NATURAL SNOW

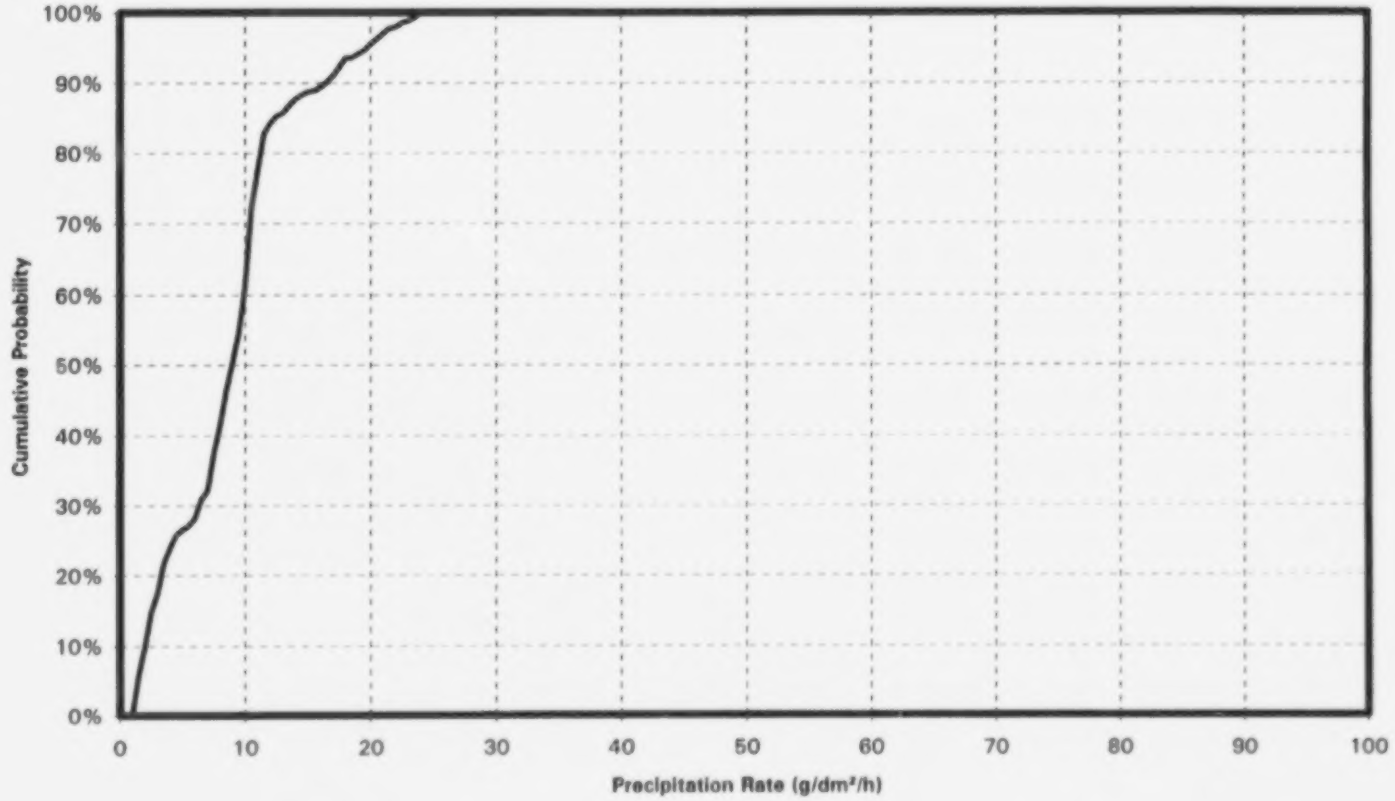
**-18 TO -22°C**

**6-MINUTE RATE EVERY MINUTE**

**1995-2001**



## READADC AND CR21X ANALYSIS - NATURAL SNOW
## -22 TO -25°C
## 35-MINUTE RATE EVERY MINUTE
## 1995-2001

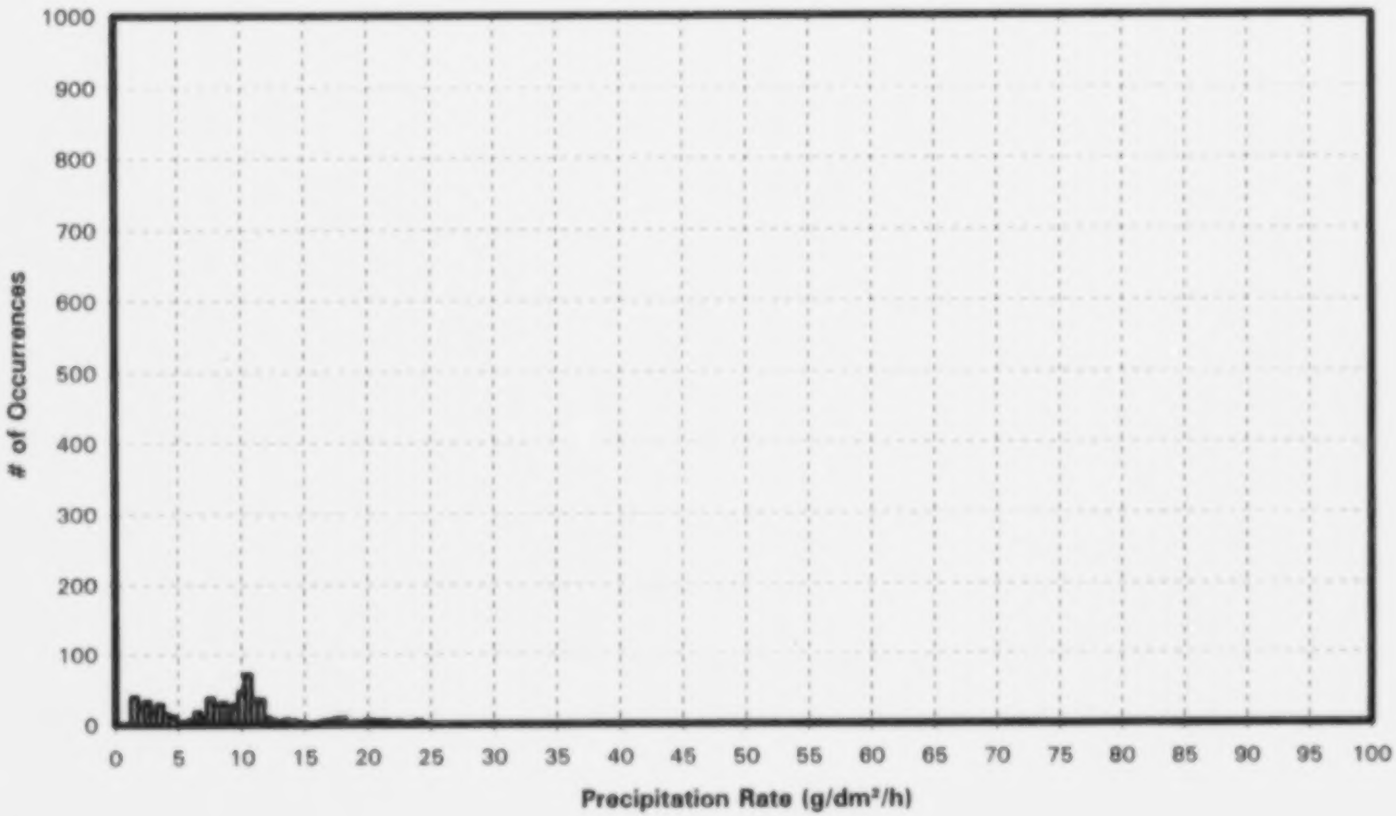


READADC AND CR21X ANALYSIS - NATURAL SNOW

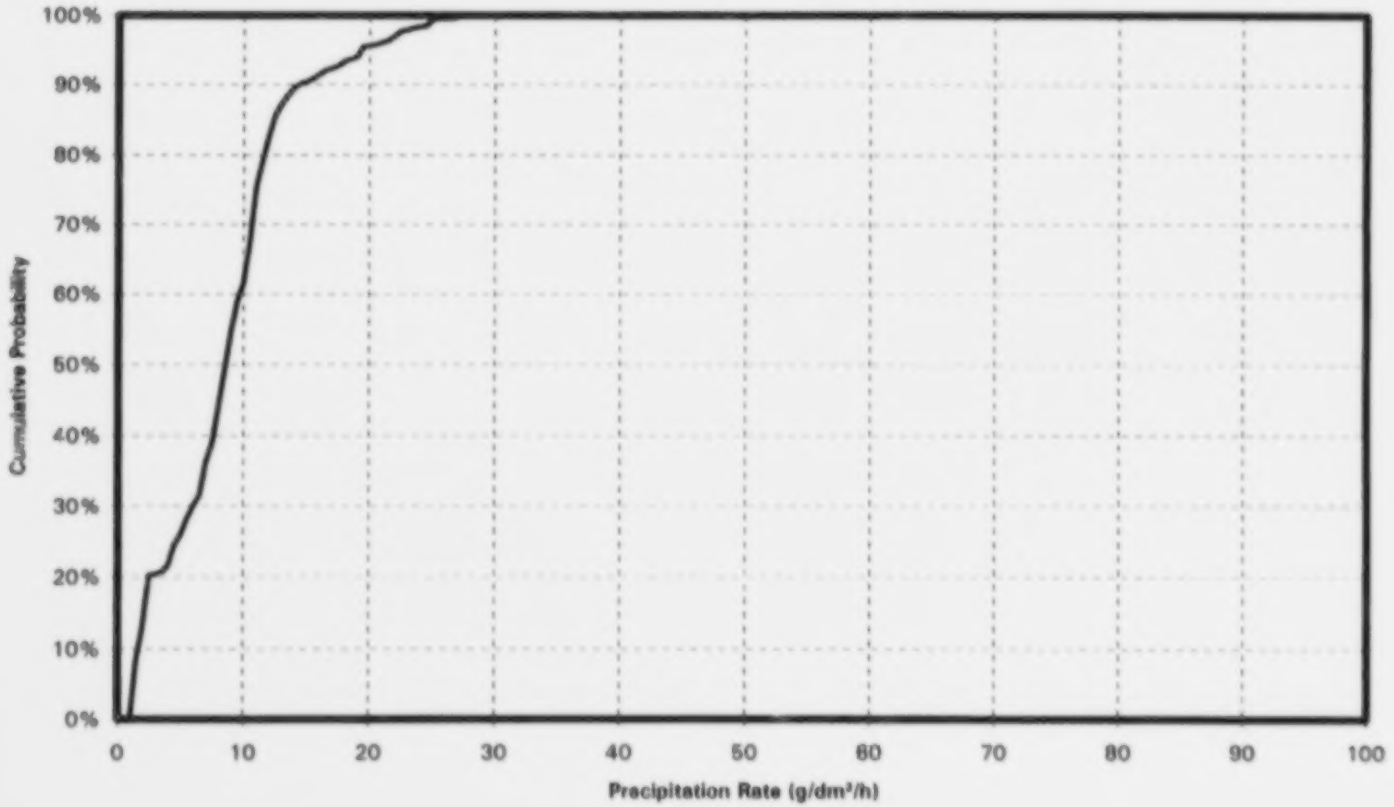
**-22 TO -25°C**

**35-MINUTE RATE EVERY MINUTE**

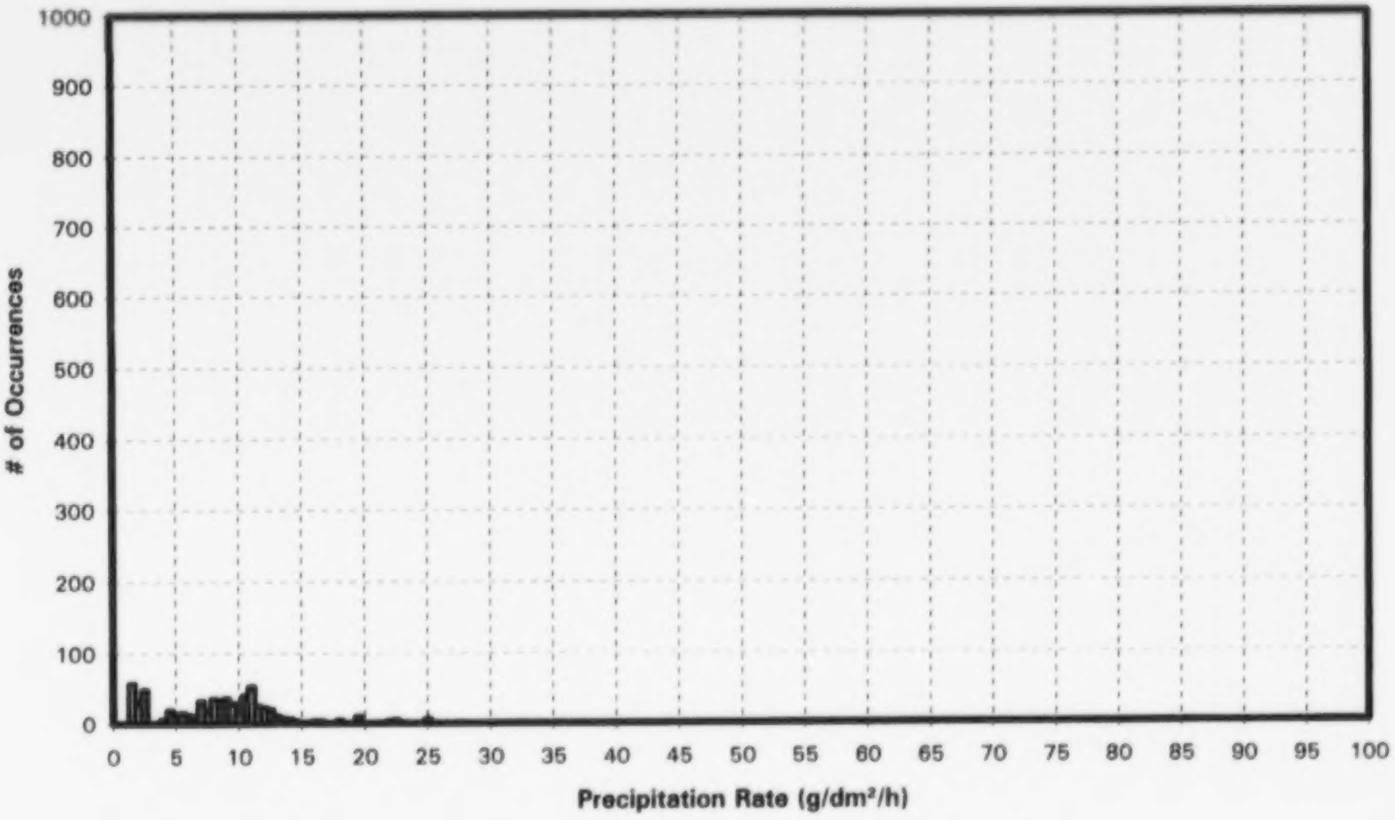
**1995-2001**



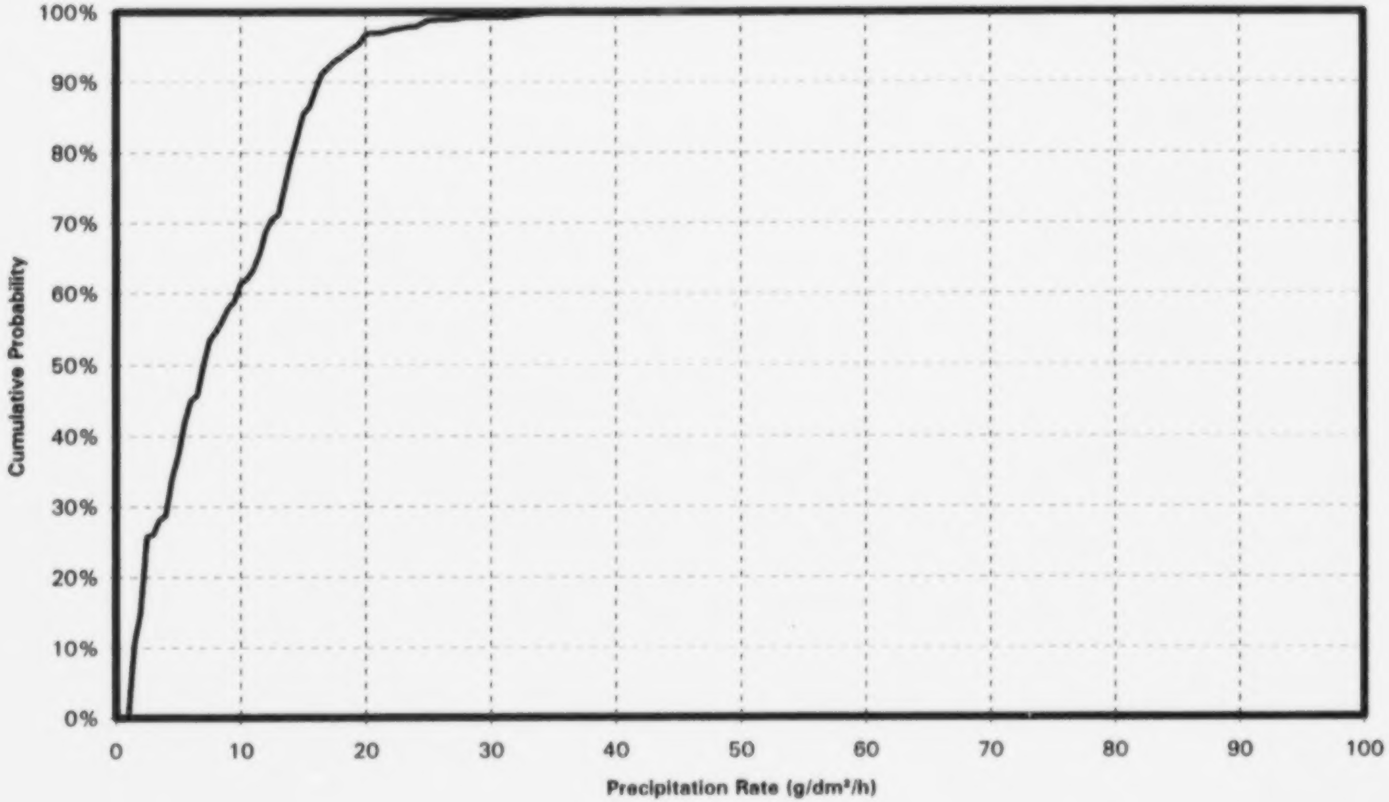
READADC AND CR21X ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-2001



READAC AND CR21X ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-2001



READAC AND CR21X ANALYSIS - NATURAL SNOW
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-2001

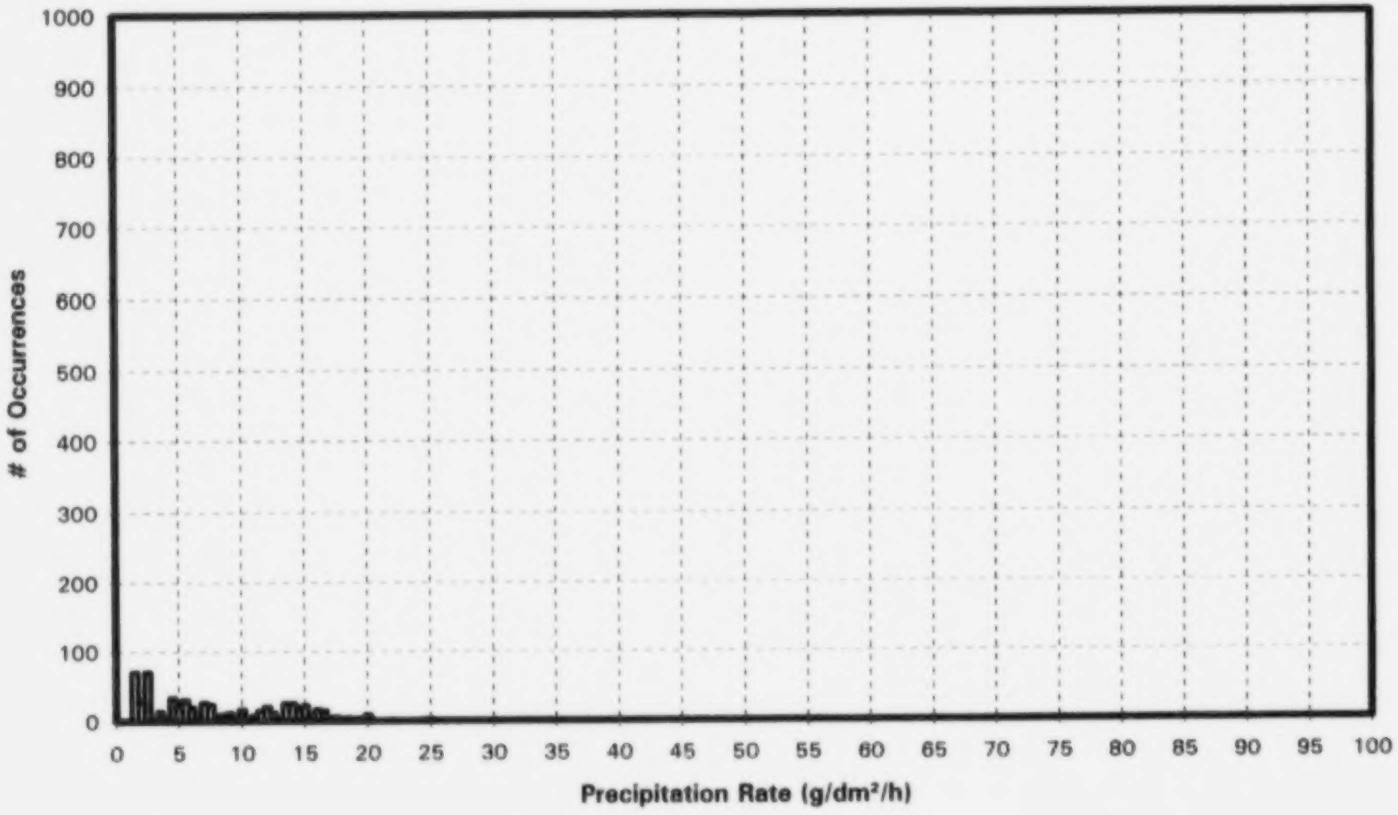


READADC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

**6-MINUTE RATE EVERY MINUTE**

**1995-2001**



# APPENDIX C

## SNOW WEATHER DATA 1993-94 AND 1994-95

# SNOW WEATHER DATA
# 1993-94 AND 1994-95

## INDEX

Page

### Distribution for Snow Accumulation

For 21 min. at every 3 min. 1993/1994 winter .... C-1
For 21 min. at every 3 min. Dec. 21, 1993 .... C-3
For 21 min. at every 3 min. Jan. 04, 1994 .... C-4
For 21 min. at every 3 min. Jan. 08, 1994 .... C-5
For 21 min. at every 3 min. Jan. 14, 1994 .... C-6
For 21 min. at every 3 min. Jan. 23, 1994 .... C-7
For 21 min. at every 3 min. Jan. 27, 1994 .... C-8
For 21 min. at every 3 min. Feb. 12, 1994 .... C-9
For 21 min. at every 3 min. Feb. 23, 1994 .... C-10
For 21 min. at every 3 min. Mar. 10, 1994 .... C-11
For 21 min. at every 3 min. Mar. 27, 1994 .... C-12
For 21 min. at every 3 min. Apr. 07, 1994 .... C-13
For 21 min. at every 3 min. Jan. 07, 1995 .... C-47
For 21 min. at every 3 min. Jan. 12, 1995 .... C-48
For 21 min. at every 3 min. Feb. 04, 1995 .... C-49
For 21 min. at every 3 min. Feb. 11, 1995 .... C-50
For 21 min. at every 3 min. Feb. 16, 1995 .... C-51
For 21 min. at every 3 min. Feb. 24, 1995 .... C-52
For 21 min. at every 3 min. Feb. 27, 1995 .... C-53
For 21 min. at every 3 min. Mar. 06, 1995 .... C-54
For 21 min. at every 3 min. Mar. 08, 1995 (morning storm) .... C-55
For 21 min. at every 3 min. Mar. 08, 1995 (afternoon storm) .... C-56
For 21 min. at every 3 min. Mar. 08-09, 1995 .... C-57
For 21 min. at every 3 min. 1994/1995 winter .... C-58
For 21 min. at every 3 min 1993/94-1994/95 winters .... C-44
For 21 min. at every 3 min 1993/94-1994/95 winters .... C-76

For 45 min. at every 3 min. Dec. 21, 1993 .... C-30
For 45 min. at every 3 min. 1993/1994 winter .... C-31
For 45 min. at every 3 min. Jan. 04, 1994 .... C-32
For 45 min. at every 3 min. Jan. 08, 1994 .... C-33
For 45 min. at every 3 min. Jan. 14, 1994 .... C-34
For 45 min. at every 3 min. Jan. 23, 1994 .... C-35
For 45 min. at every 3 min. Jan. 27, 1994 .... C-36
For 45 min. at every 3 min. Feb. 12, 1994 .... C-37
For 45 min. at every 3 min. Feb. 23, 1994 .... C-38
For 45 min. at every 3 min Mar. 10, 1994 .... C-39
For 45 min. at every 3 min. Mar 27, 1994 .... C-40
For 45 min. at every 3 min. Apr. 07, 1994 .... C-41
For 45 min. at every 3 min. Jan. 07, 1995 .... C-61
For 45 min. at every 3 min. Jan. 12, 1995 .... C-62
For 45 min. at every 3 min. Feb. 04, 1995 .... C-63
For 45 min. at every 3 min. Feb. 11, 1995 .... C-64
For 45 min. at every 3 min. Feb. 16, 1995 .... C-65
For 45 min. at every 3 min. Feb. 24, 1995 .... C-66
For 45 min. at every 3 min. Feb. 27, 1995 .... C-67

# SNOW WEATHER DATA
# 1993-94 AND 1994-95

## INDEX Page

For 45 min. at every 3 min. Mar. 06, 1995 ........ C-68
For 45 min. at every 3 min. Mar. 08, 1995 (morning storm) ........ C-69
For 45 min. at every 3 min. Mar. 08, 1995 (afternoon storm) ........ C-70
For 45 min. at every 3 min. Mar. 08-09, 1995 ........ C-71
For 45 min. at every 3 min. 1994/1995 winter ........ C-42
For 45 min. at every 3 min. 1994/1995 winter ........ C-59
For 45 min. at every 3 min. 1993/94-1994/95 winters ........ C-72
For 45 min. at every 3 min. 1993/94-1994/95 winters ........ C-74

## Histogram for Snow Accumulation

For 21 min. at every 3 min. for 1993/1994 winter ........ C-2
For 21 min. at every 3 min. for 1994/1995 winter ........ C-43
For 21 min. at every 3 min for 1994/1995 winter ........ C-46
For 21 min. at every 3 min 1993/94-1994/95 winters ........ C-46

For 45 min. at every 3 min. 1994/1995 winter ........ C-60
For 45 min. at every 3 min. 1993/94-1994/95 winters ........ C-73
For 45 min. at every 3 min. 1993/94-1994/95 winters ........ C-75

Every 21 min. Series 1, Jan. 4, 1994 ........ C-29

## Total Snow Accumulation

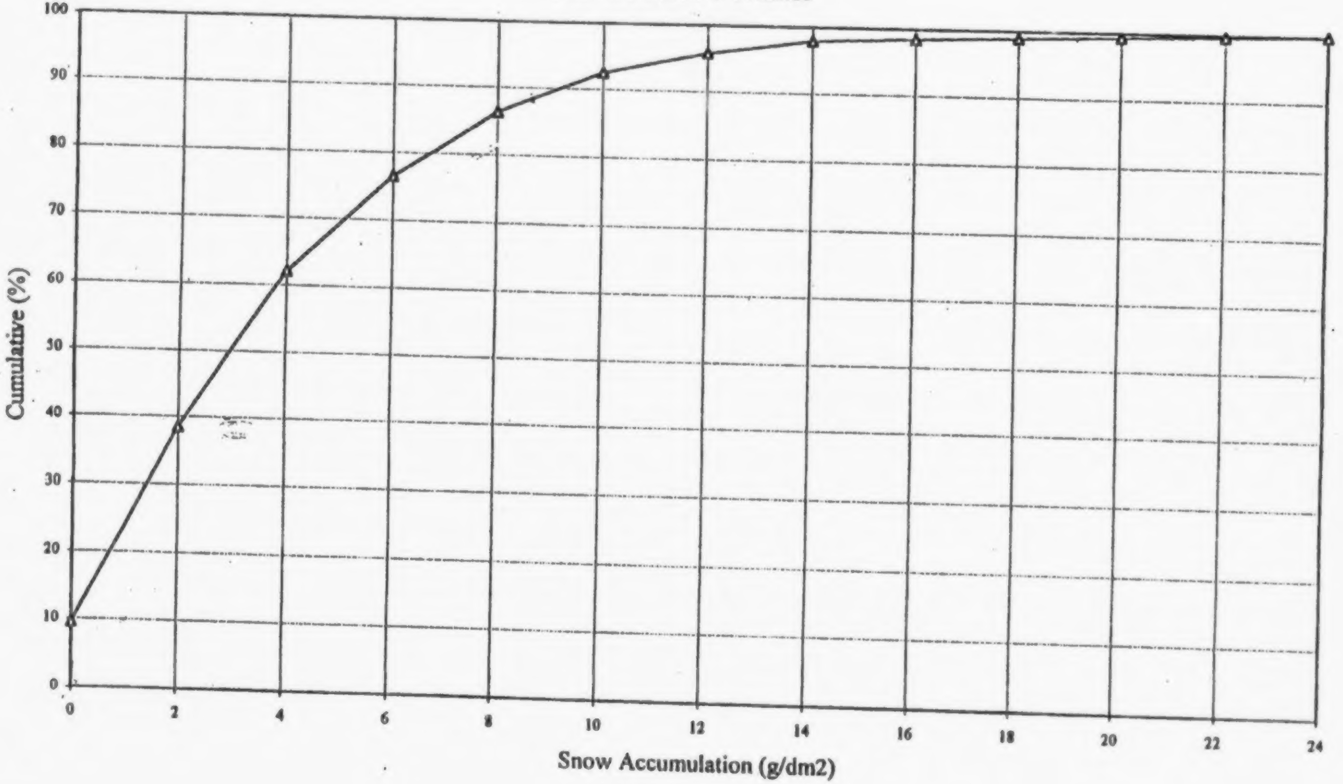
For Dec. 21, 1993 ........ C-14
For Dec. 21, 1993 ........ C-15
For Jan. 04, 1994 ........ C-16
For Jan. 04, 1994 ........ C-17
For Jan. 08, 1994 ........ C-18
For Jan. 14, 1994 ........ C-19
For Jan. 23, 1994 ........ C-20
For Jan. 27, 1993 ........ C-21
For Feb. 12-13, 1993 ........ C-22
For Feb. 23-24, 1994 ........ C-23
For Feb. 23-24, 1994 ........ C-24
For Mar. 10, 1994 ........ C-25
For Mar. 27, 1994 ........ C-26
For Apr. 07, 1994 ........ C-27

## Comparison Between Moving & Reg. Averages for Distribution for Snow Accumulation

Jan. 4, 1994 ........ C-28

## Moving average

1994/1995 ........ C-45

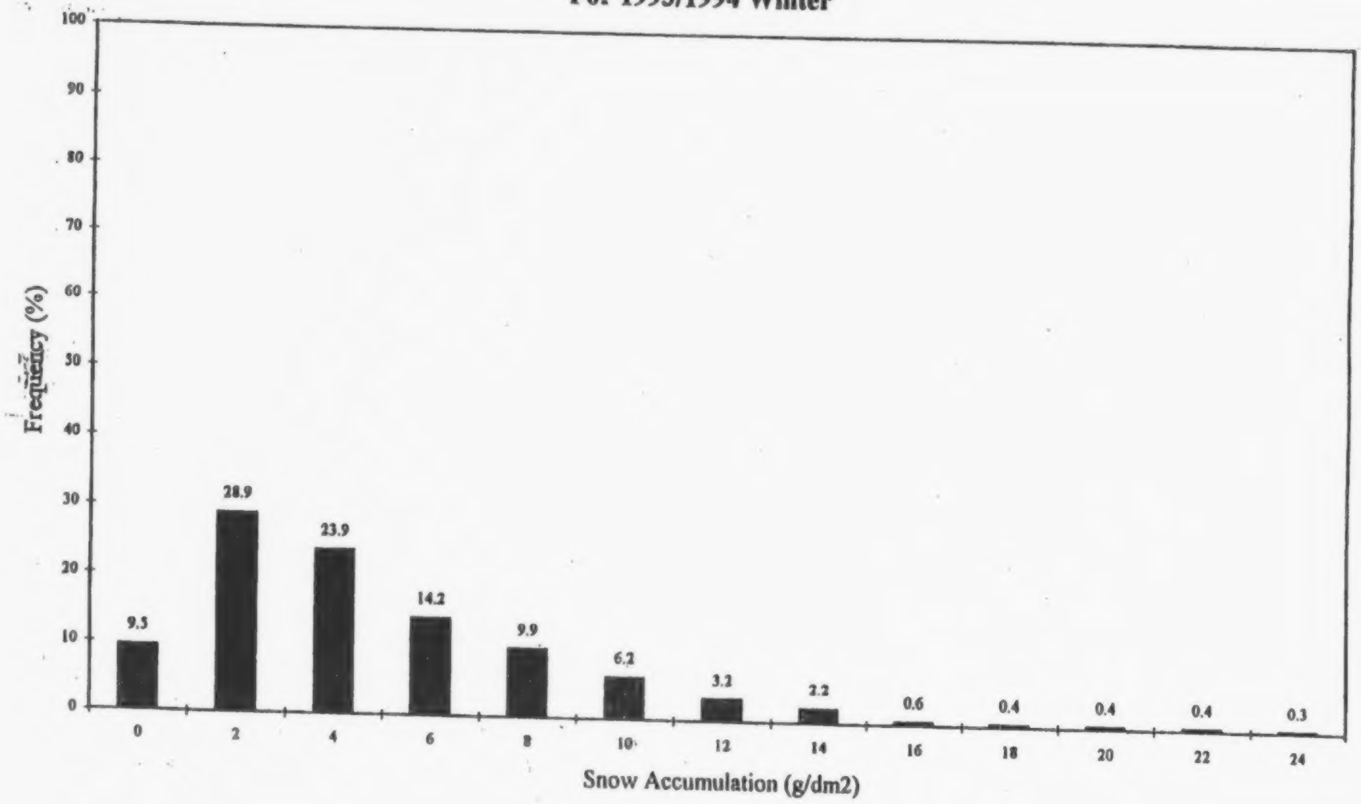


**Distribution for Snow Accumulation**
**For 21 min. at Every 3 min.**
**For 1993/1994 Winter**

18/8/95 15:29

MHIST94.XLS

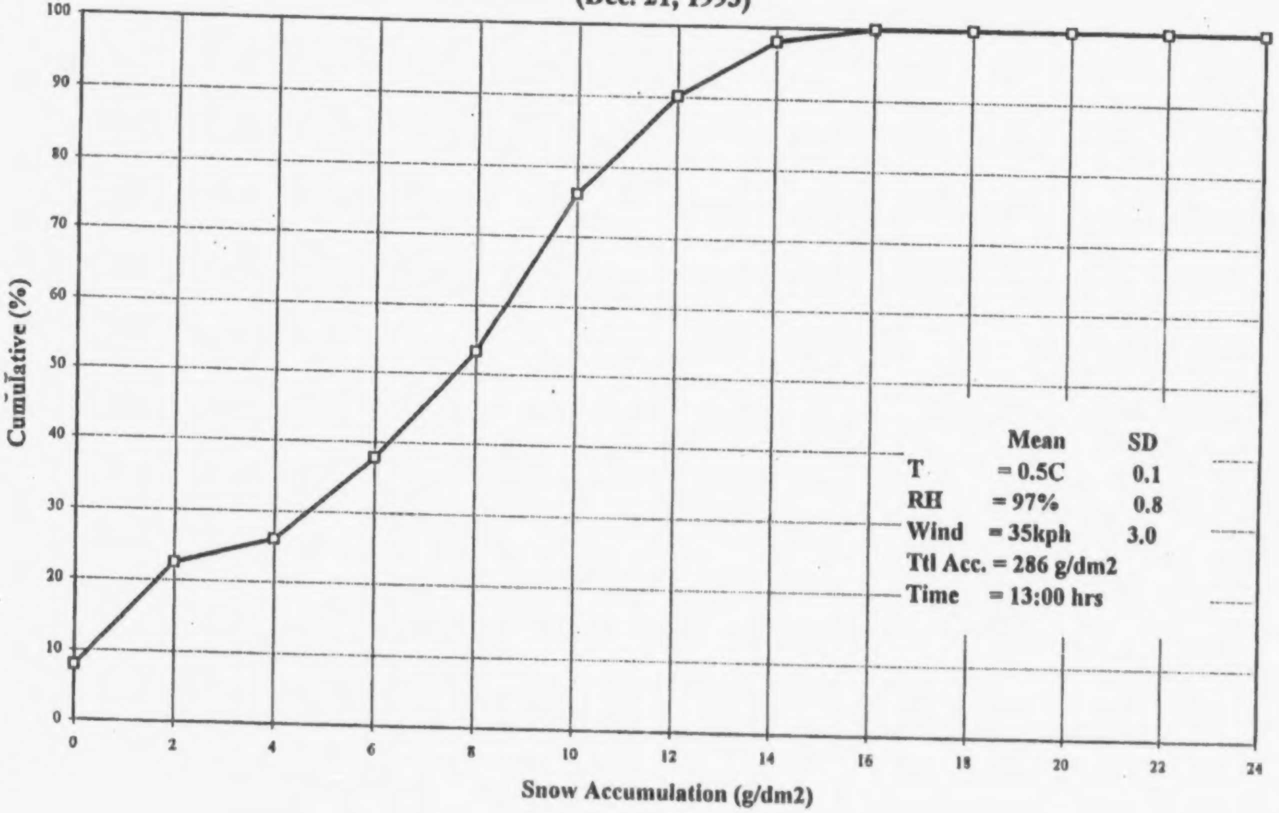
## Histogram for Snow Accumulation
## For 21 min. at Every 3 min.
## For 1993/1994 Winter



17/8/95 09:45

MHIST94.XLS

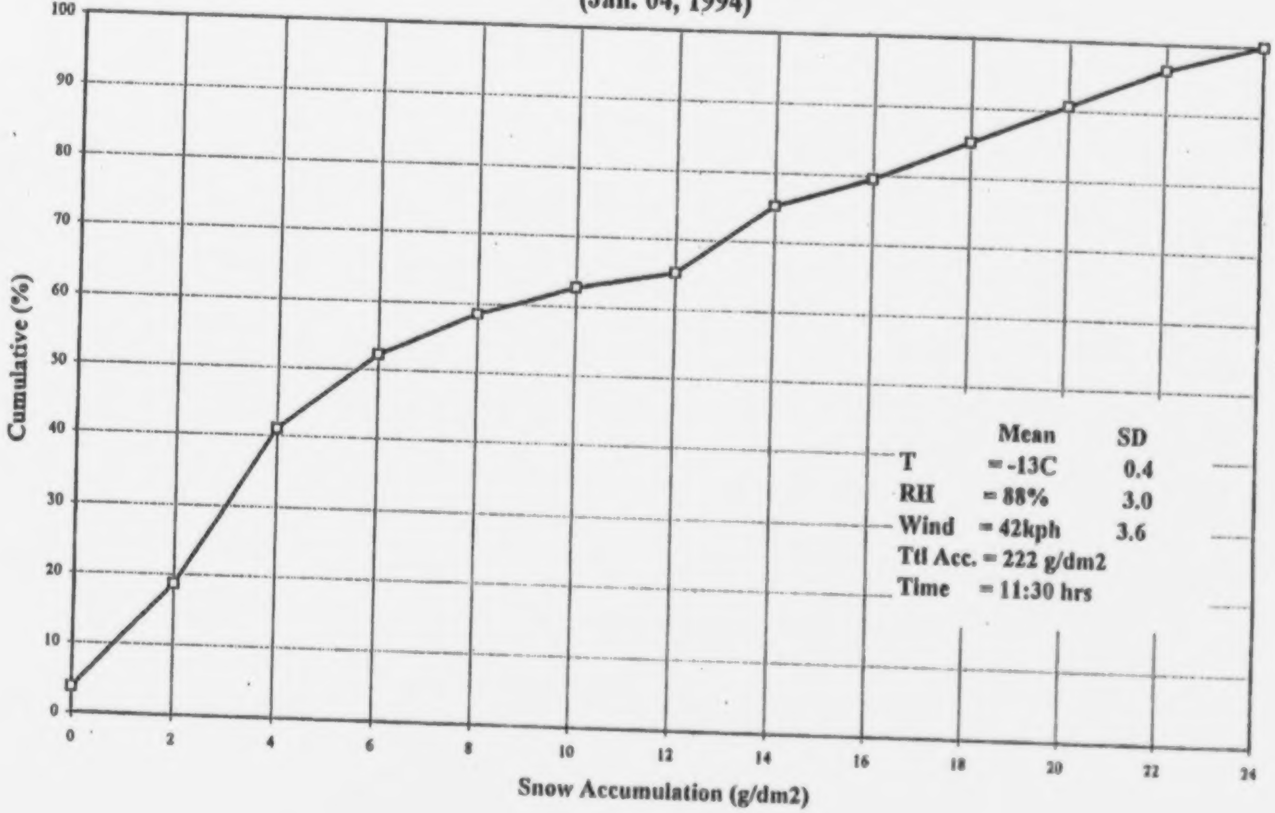
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Dec. 21, 1993)**



6/8/95 15:13

DEC2193.XL

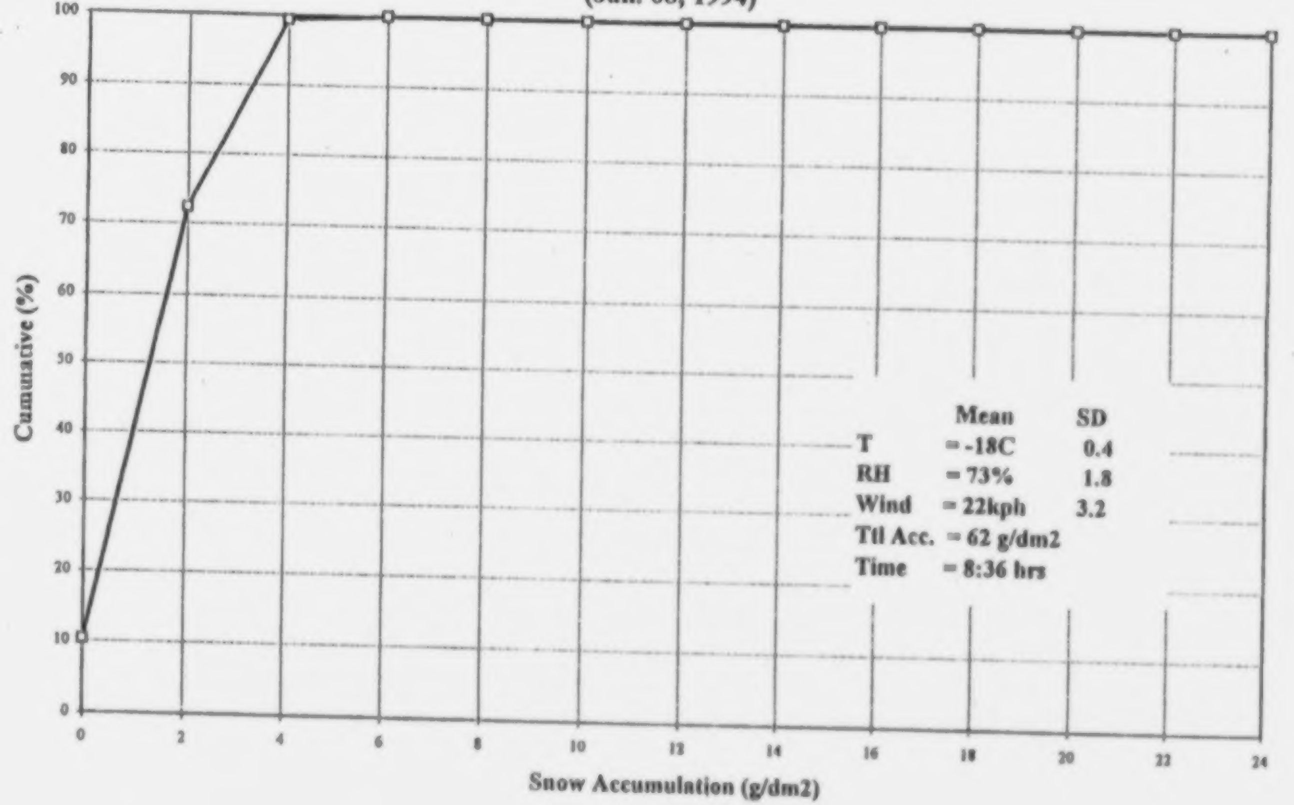
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Jan. 04, 1994)**



16/8/95 15:11

JAN0494.XLS

## Distribution of Snow Accumulation
## For 21 min. at Every 3 min.
## (Jan. 08, 1994)



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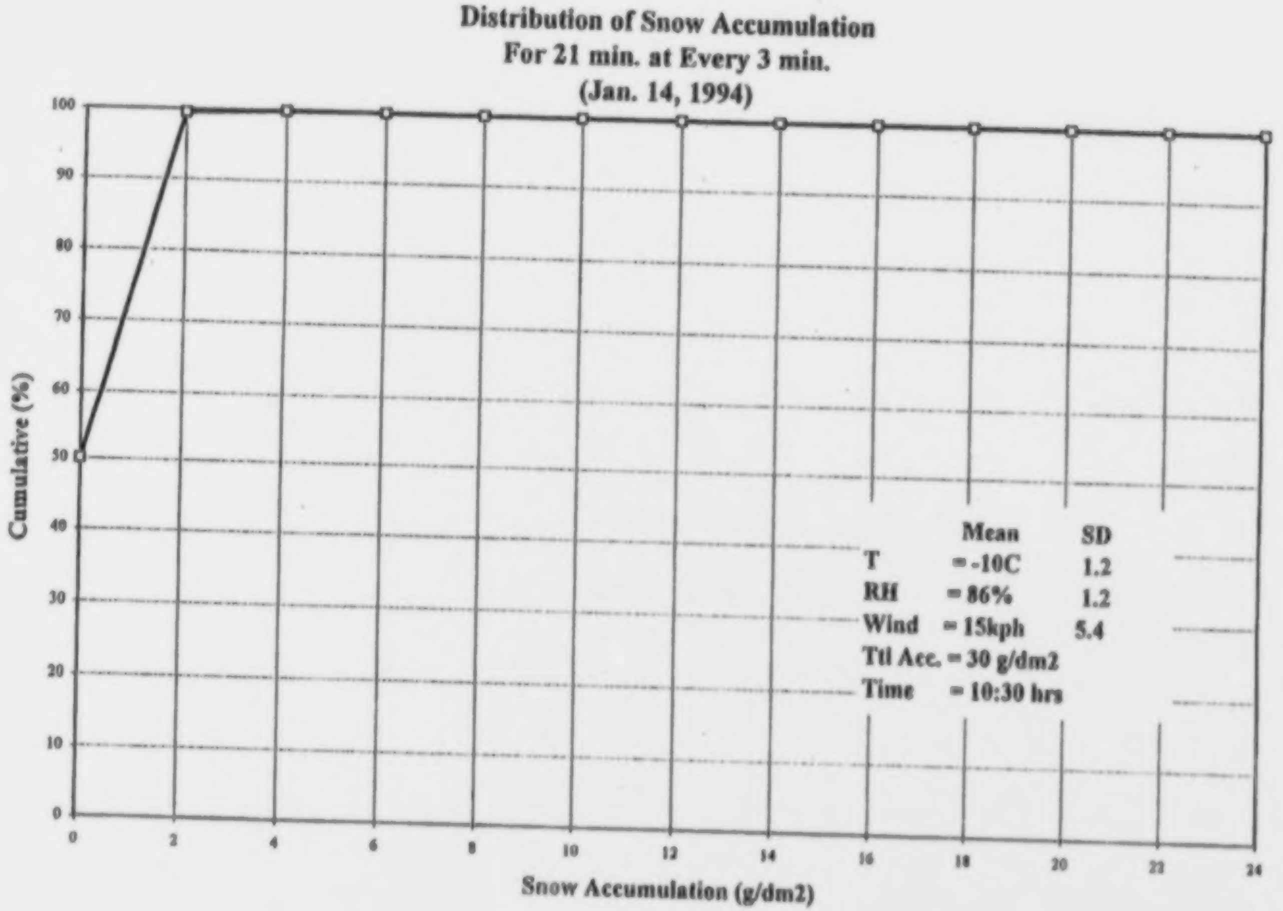
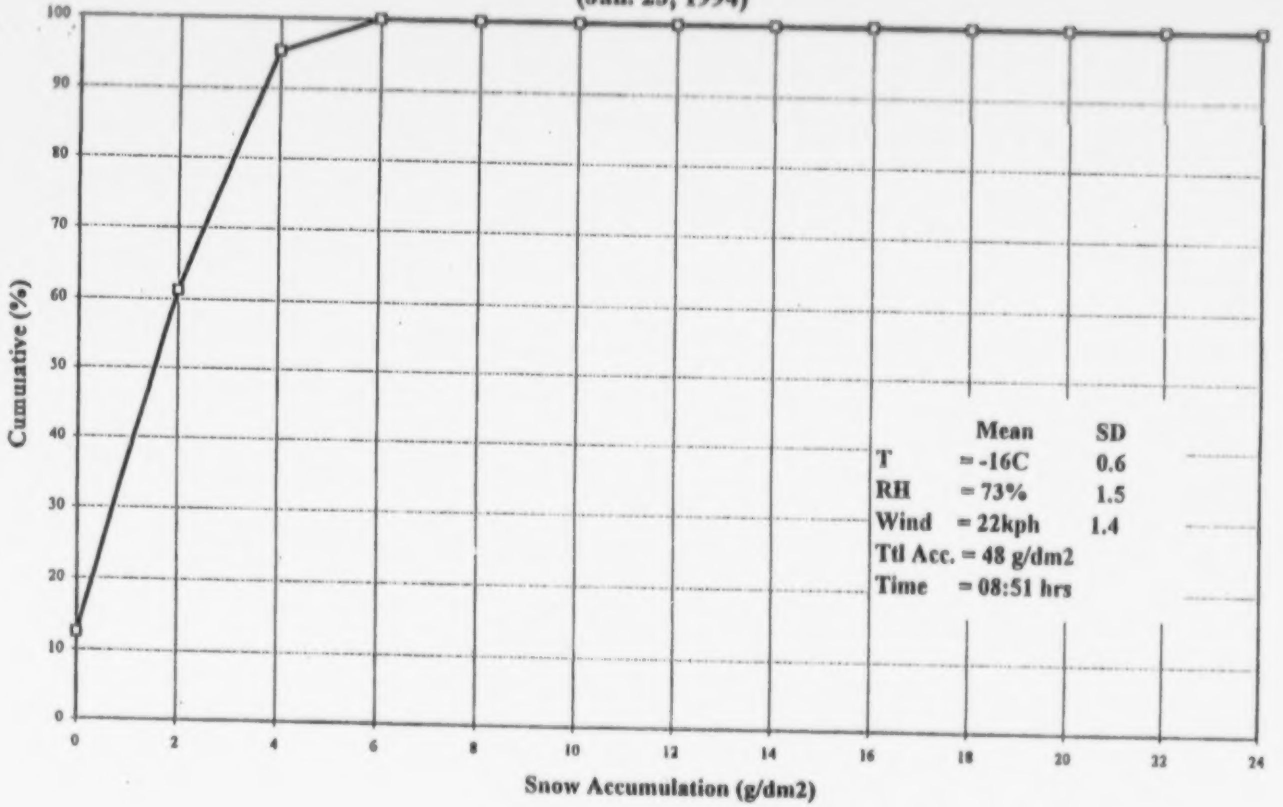


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 14, 1994)

18/8/95 16:22

JAN1494.XLS

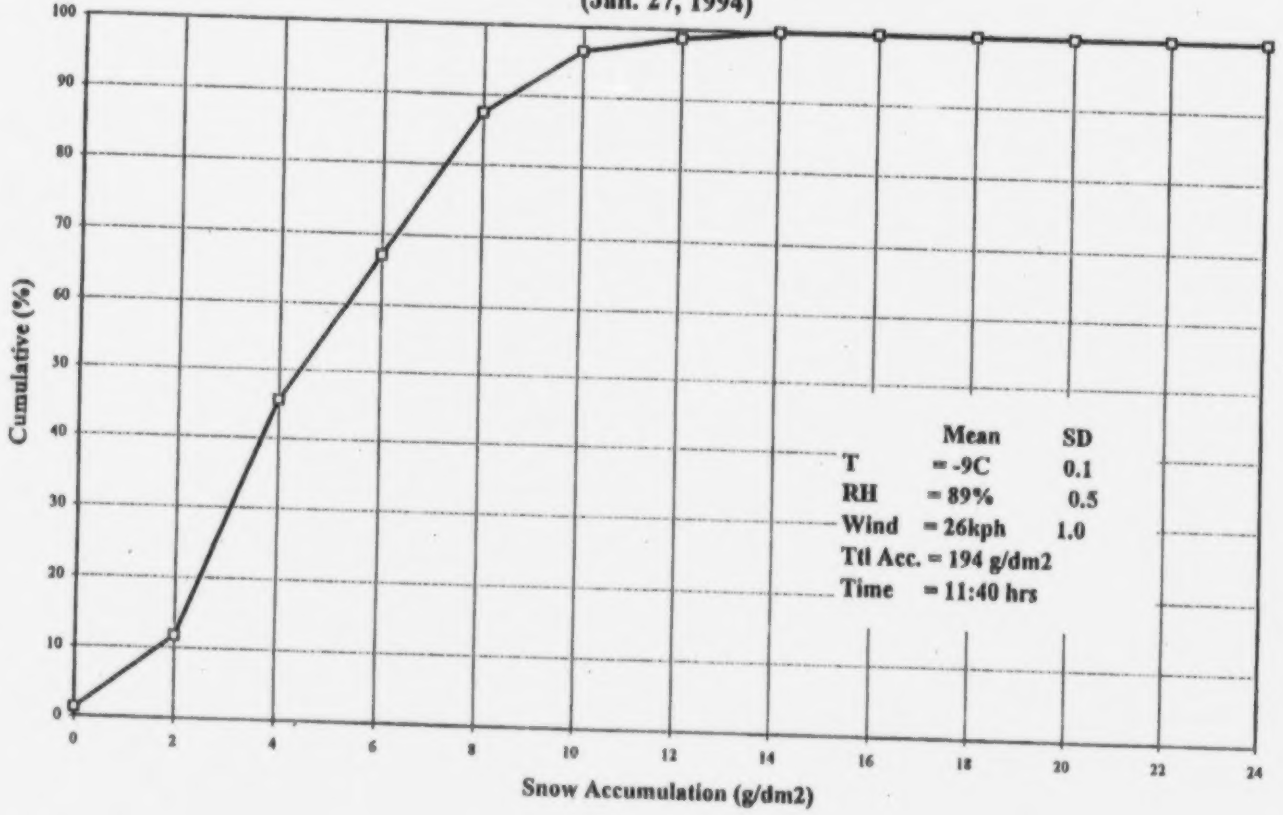


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 23, 1994)

17/8/95 16:00

JAN2394.XLS

**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Jan. 27, 1994)**



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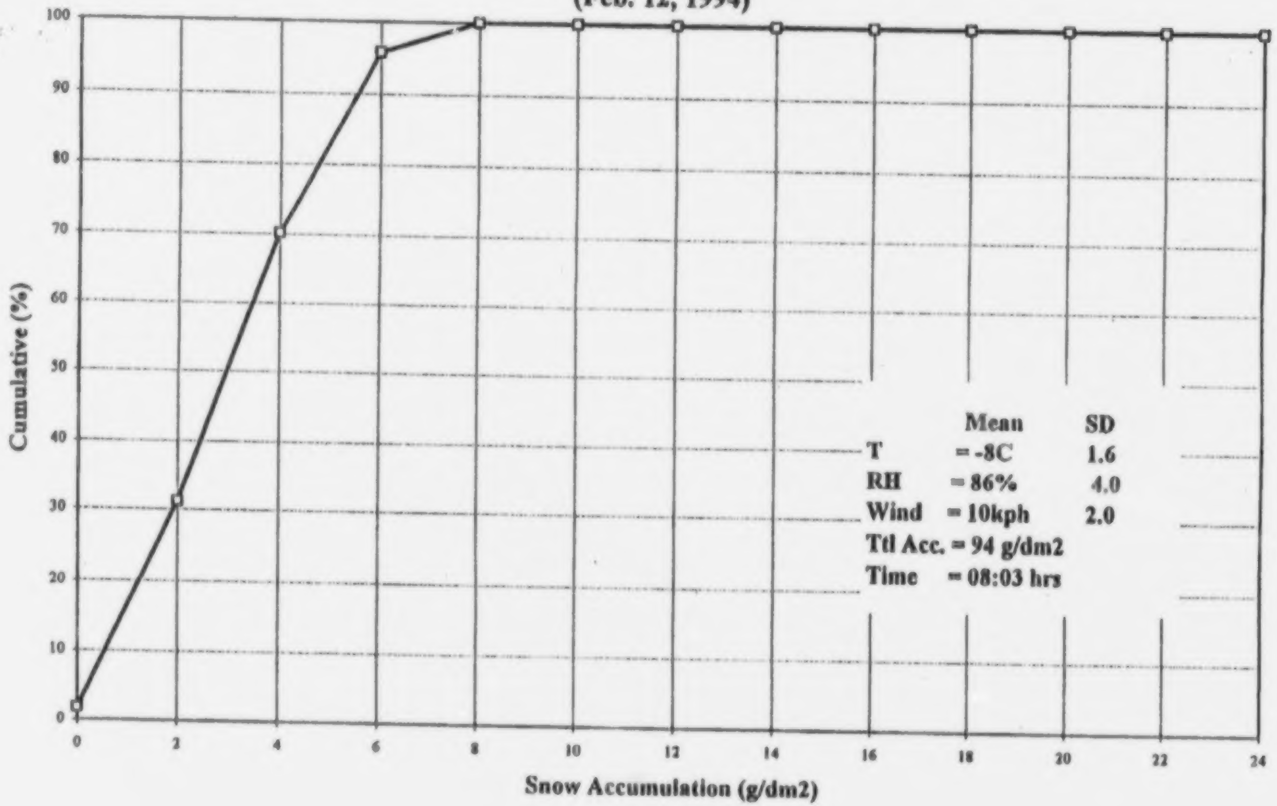
JAN2794.XLS

## Distribution of Snow Accumulation For 21 min. at Every 3 min. (Feb. 12, 1994)



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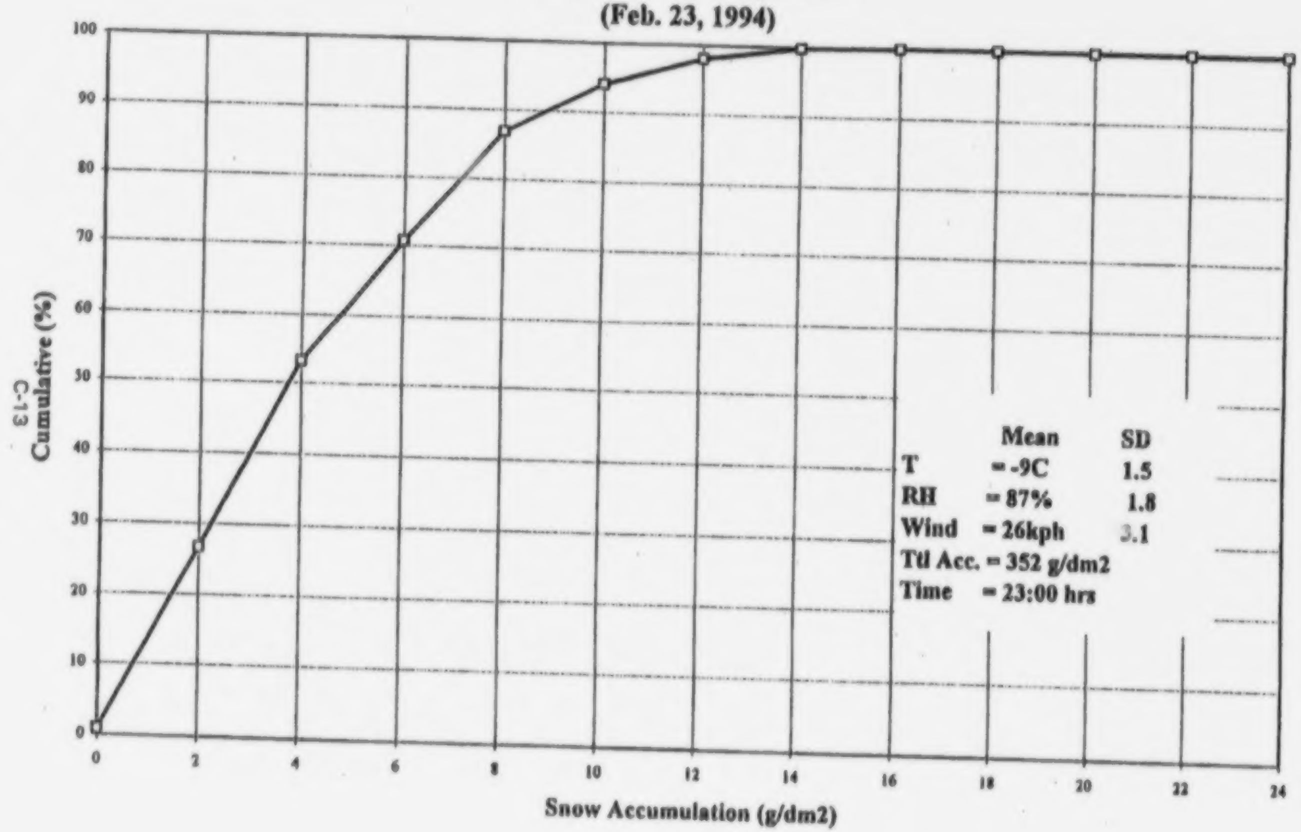
FEB1294.XLS

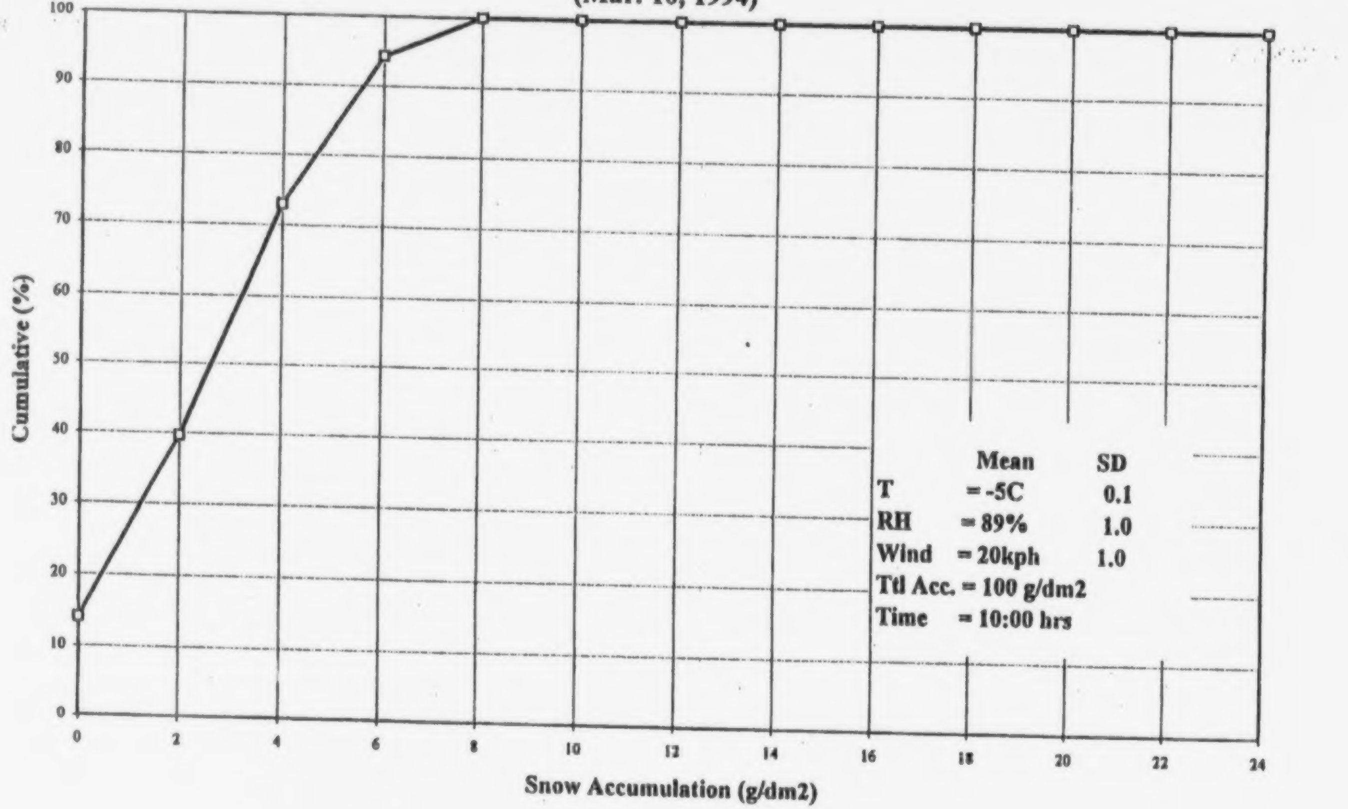
## Distribution for Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 23, 1994)



16/8/95 15:21

FEB2394.XLS

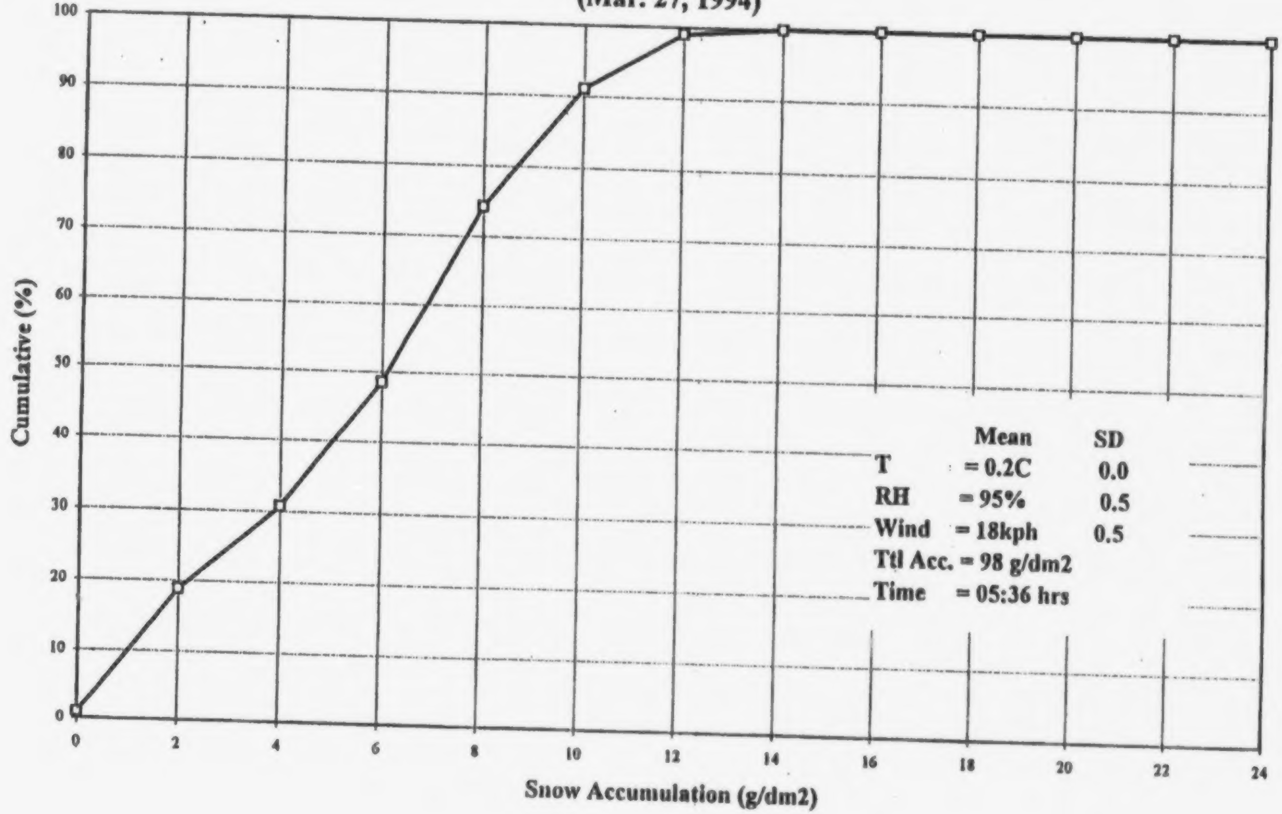
## Distribution of Snow Accumulation
## For 21 min. at Every 3 min.
## (Mar. 10, 1994)



16/8/95 14:59

MAR1094.XLS

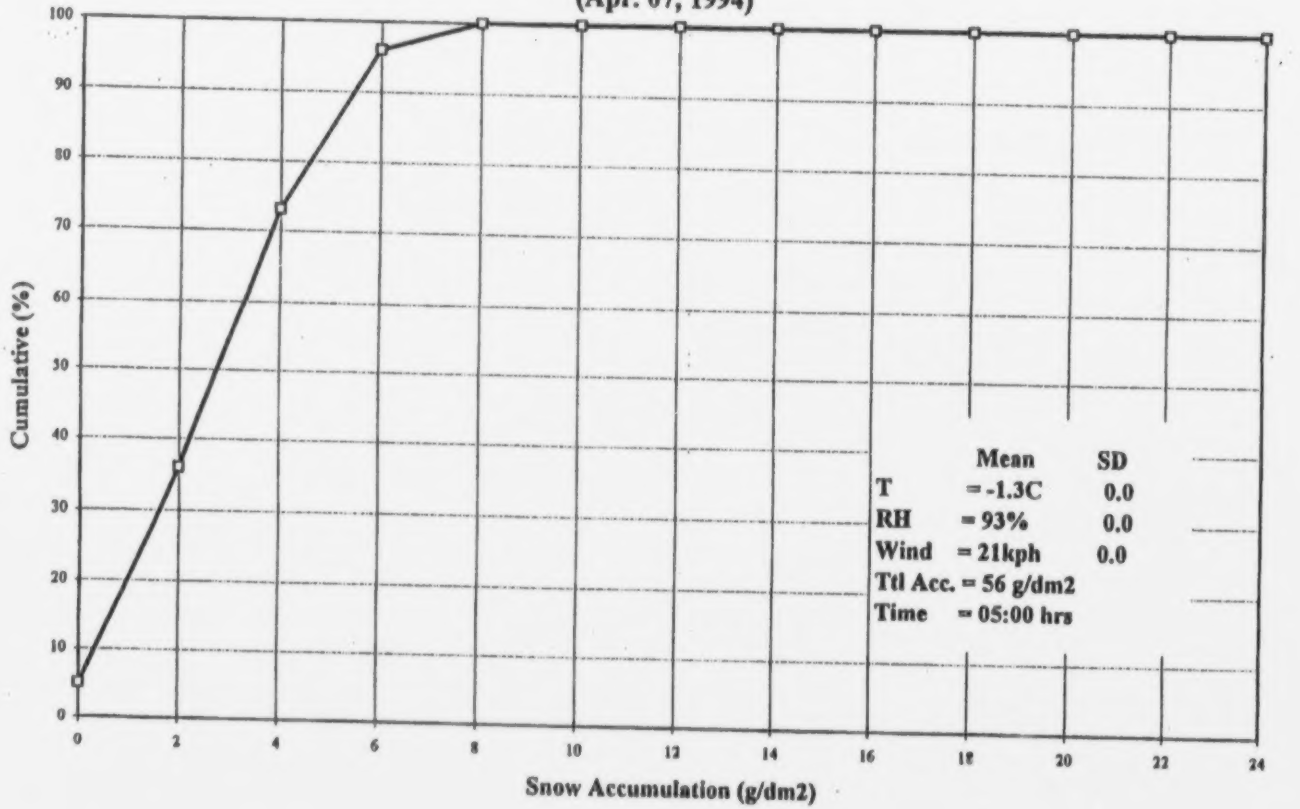
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Mar. 27, 1994)**



18/8/95 16:30

MAR2794.XLS

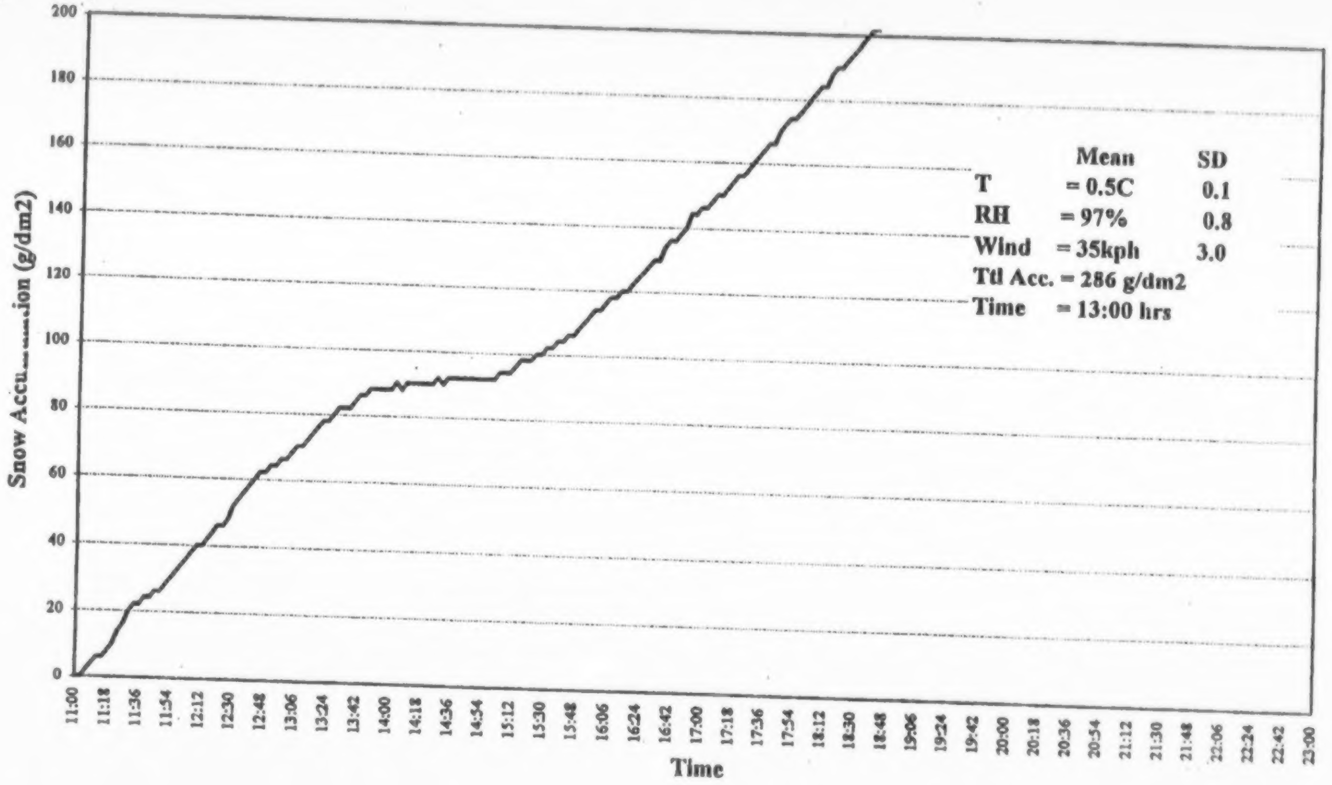
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Apr. 07, 1994)**



17/8/95 16:37

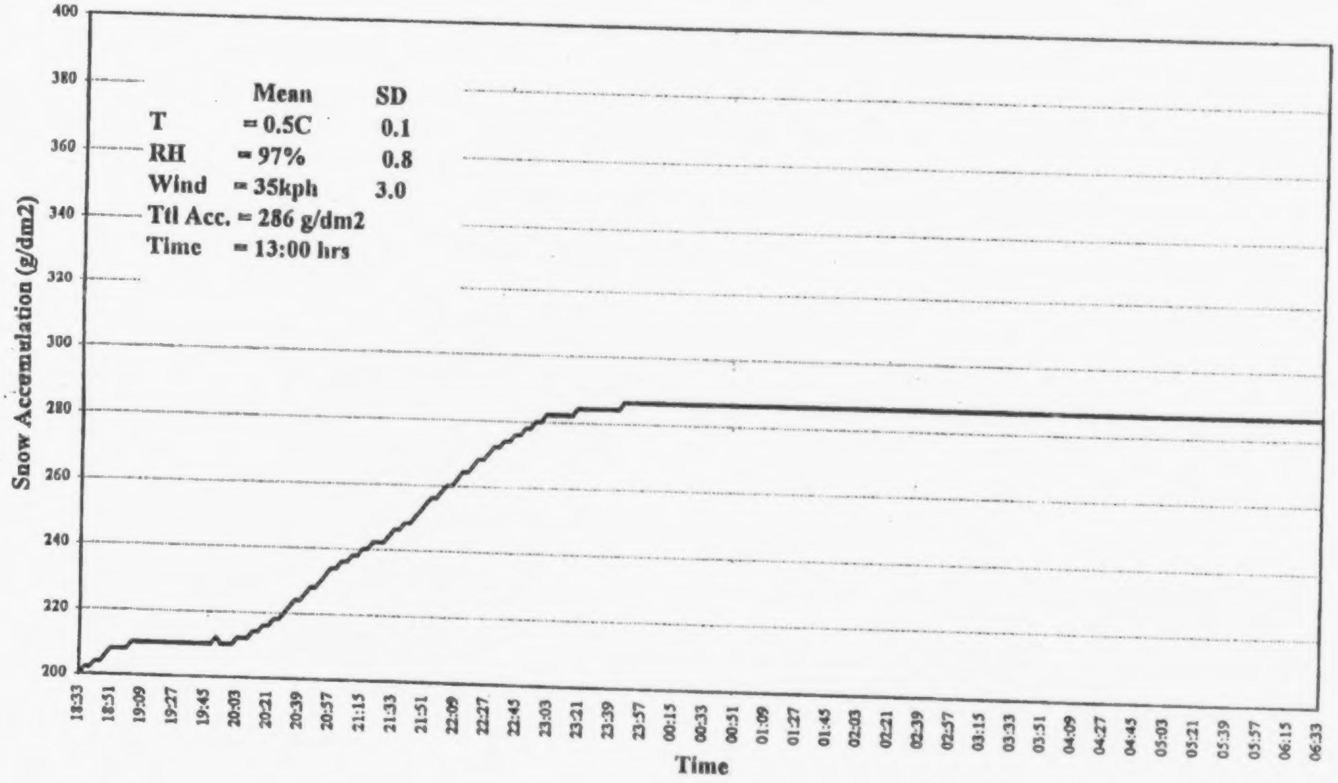
APR0794 XLS

## Total Snow Accumulation for Dec. 21, 1993



14/8/95 15:04

## Total Snow Accumulation
## for Dec. 21, 1993



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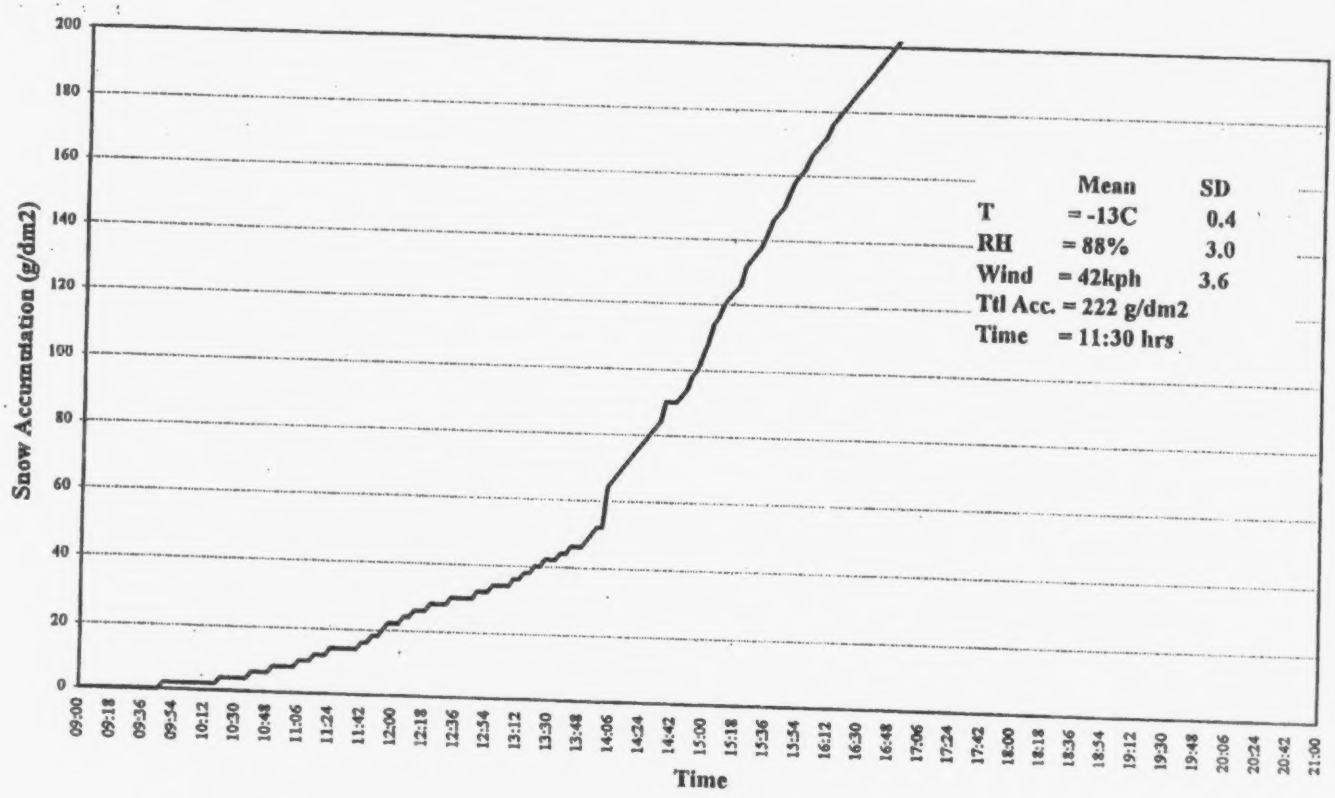
DEC2193.XLS

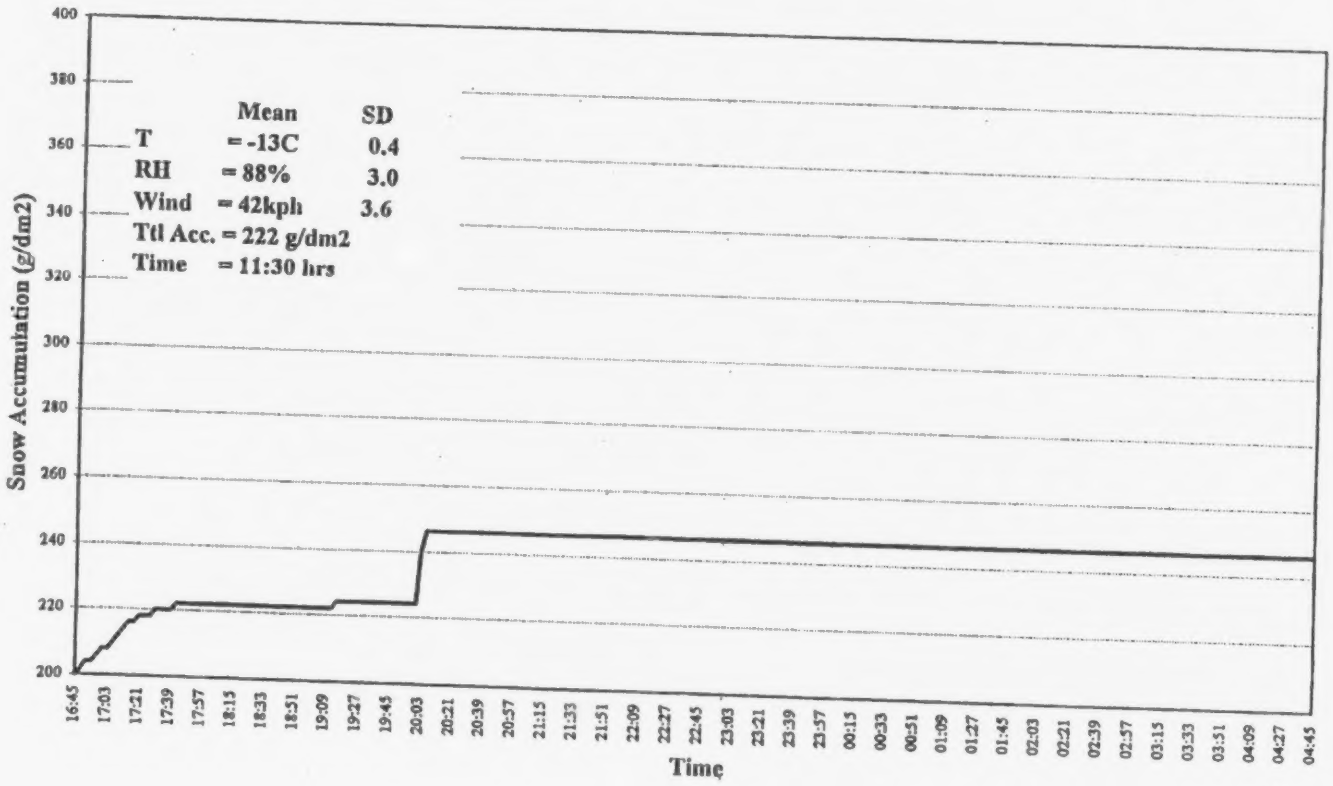
Total Snow Accumulation
for Jan 04, 1994



4/8/95 15:29

JAN0494.XLS

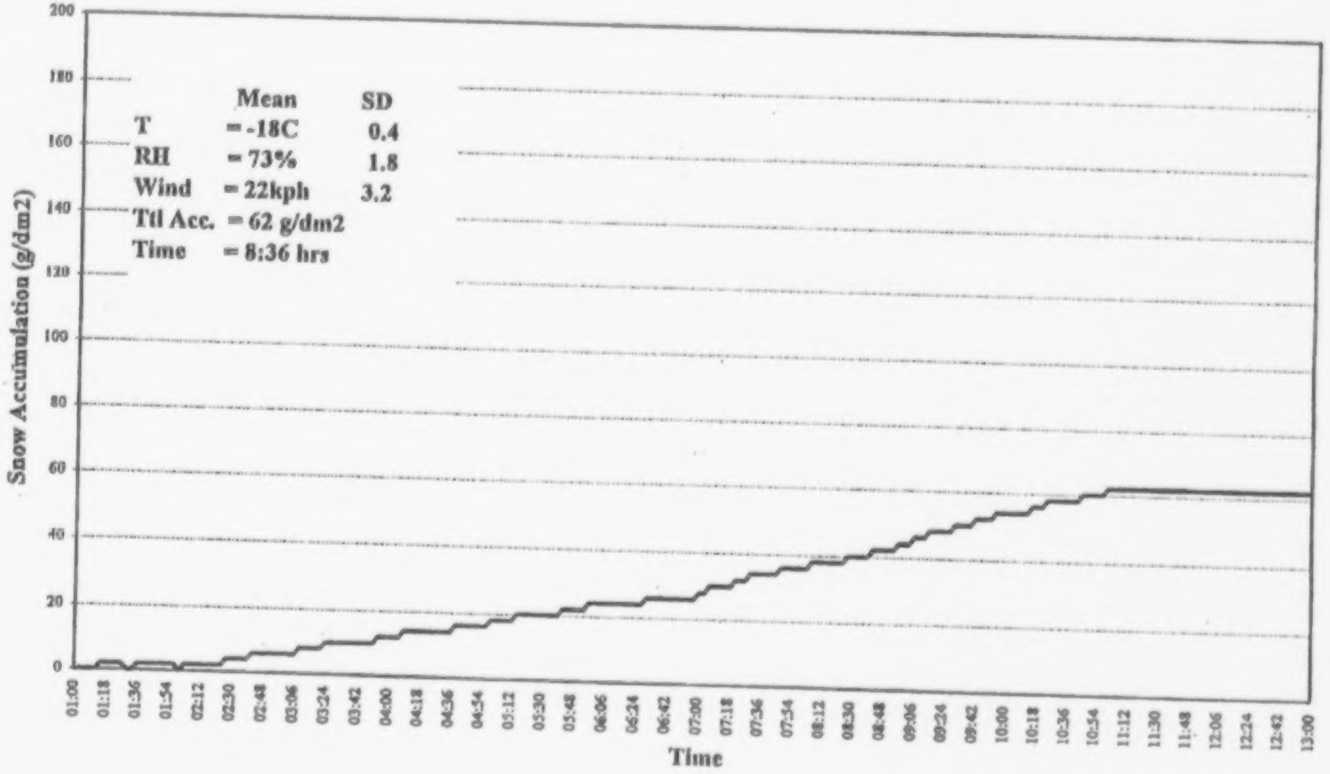
## Total Snow Accumulation
## for Jan 04, 1994



4/8/95 15:28

JAN0494.XLS

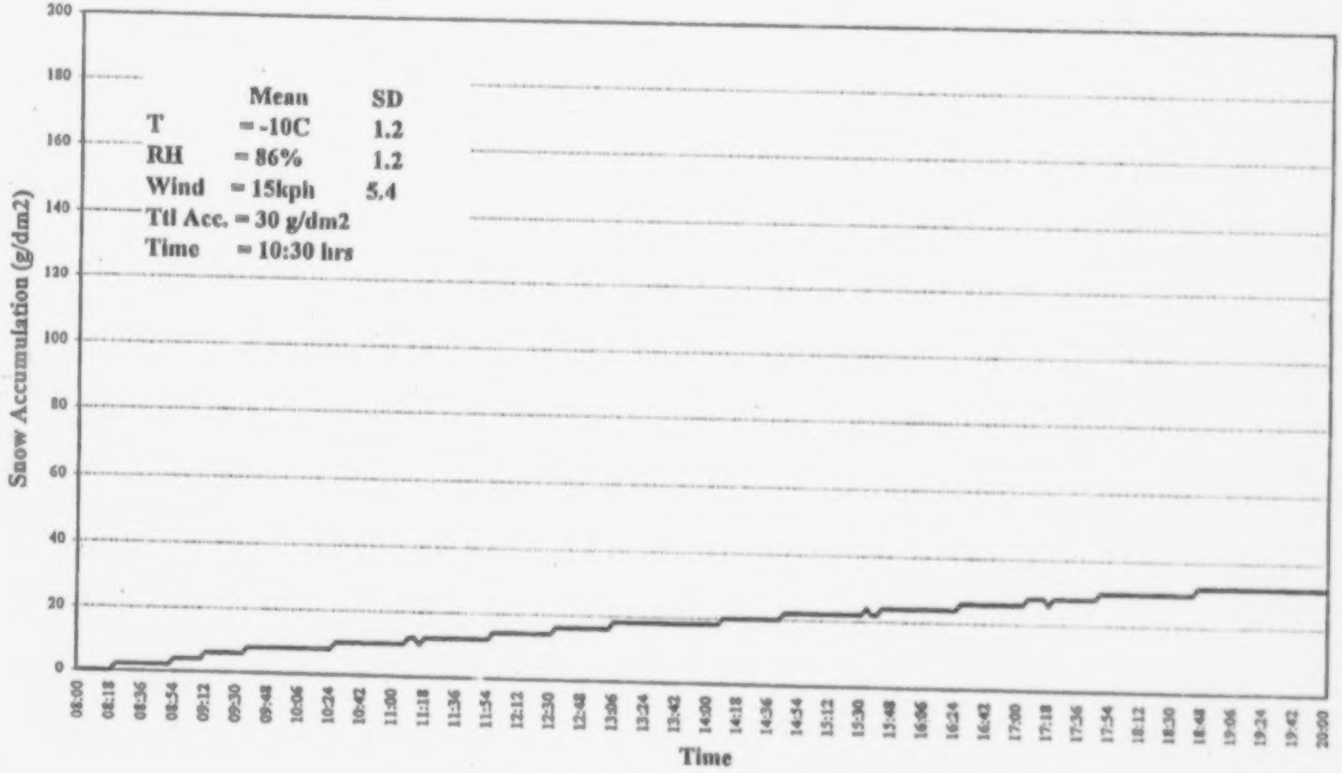
**Total Snow Accumulation**
**for Jan. 08, 1994**



14/8/95 15:23

JAN0894.XLS

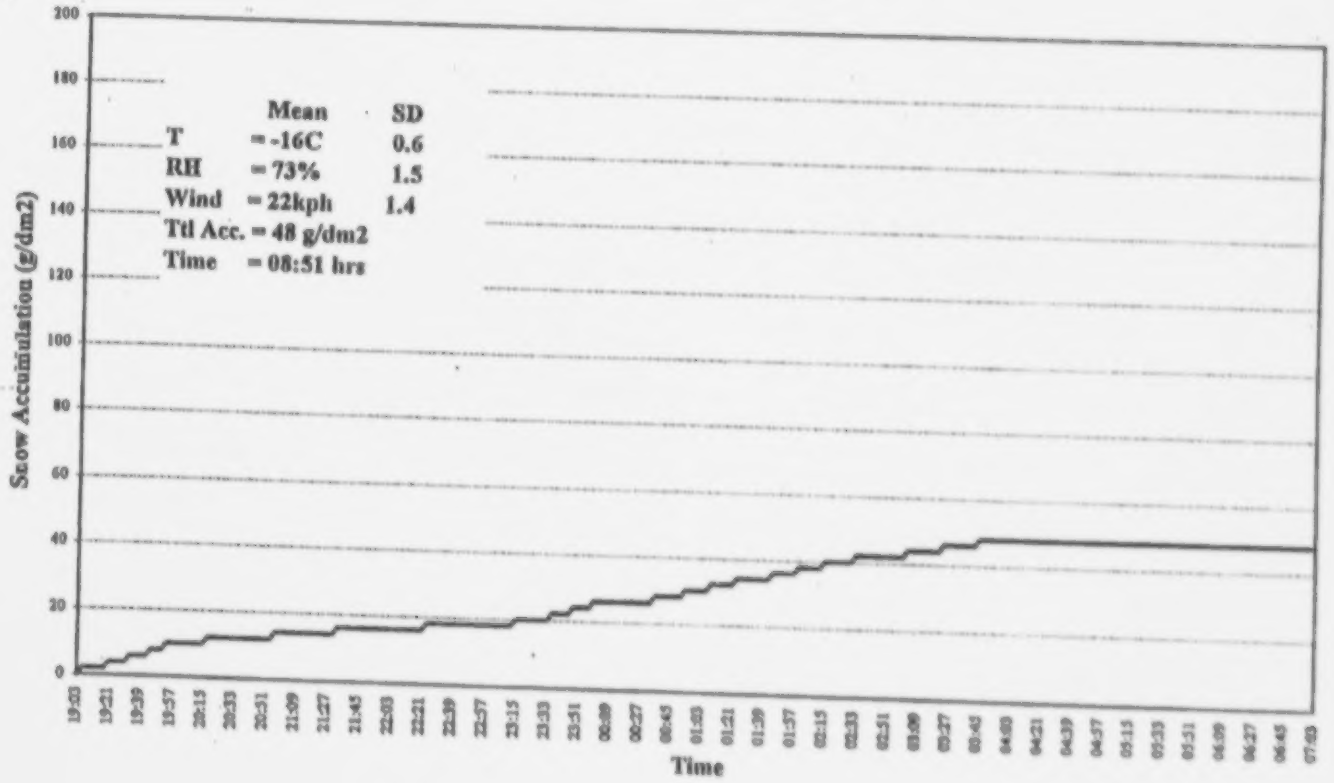
## Total Snow Accumulation
## for Jan 14, 1994



14/8/95 15:44

JAN1494.XLS

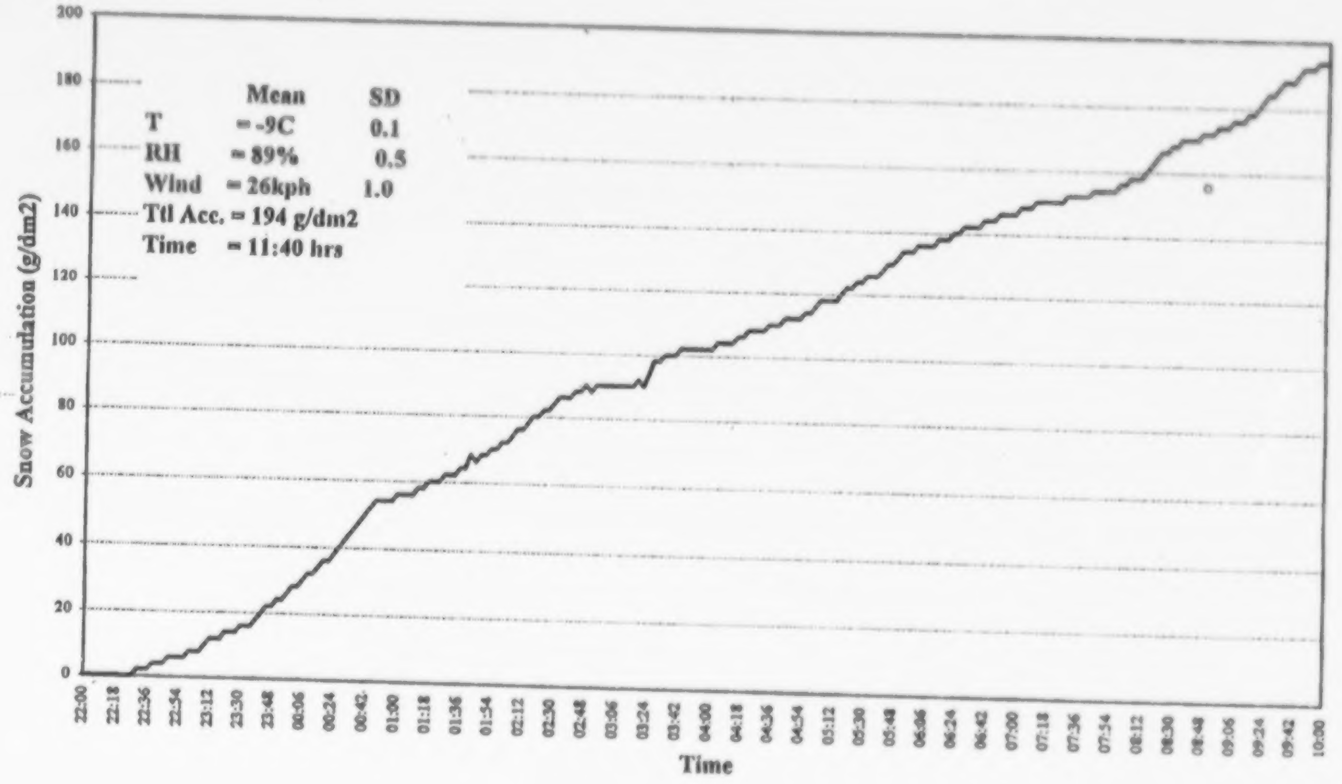
Total Snow Accumulation
for Jan. 23, 1994



14/8/95 15:25

JAN2394.XLS

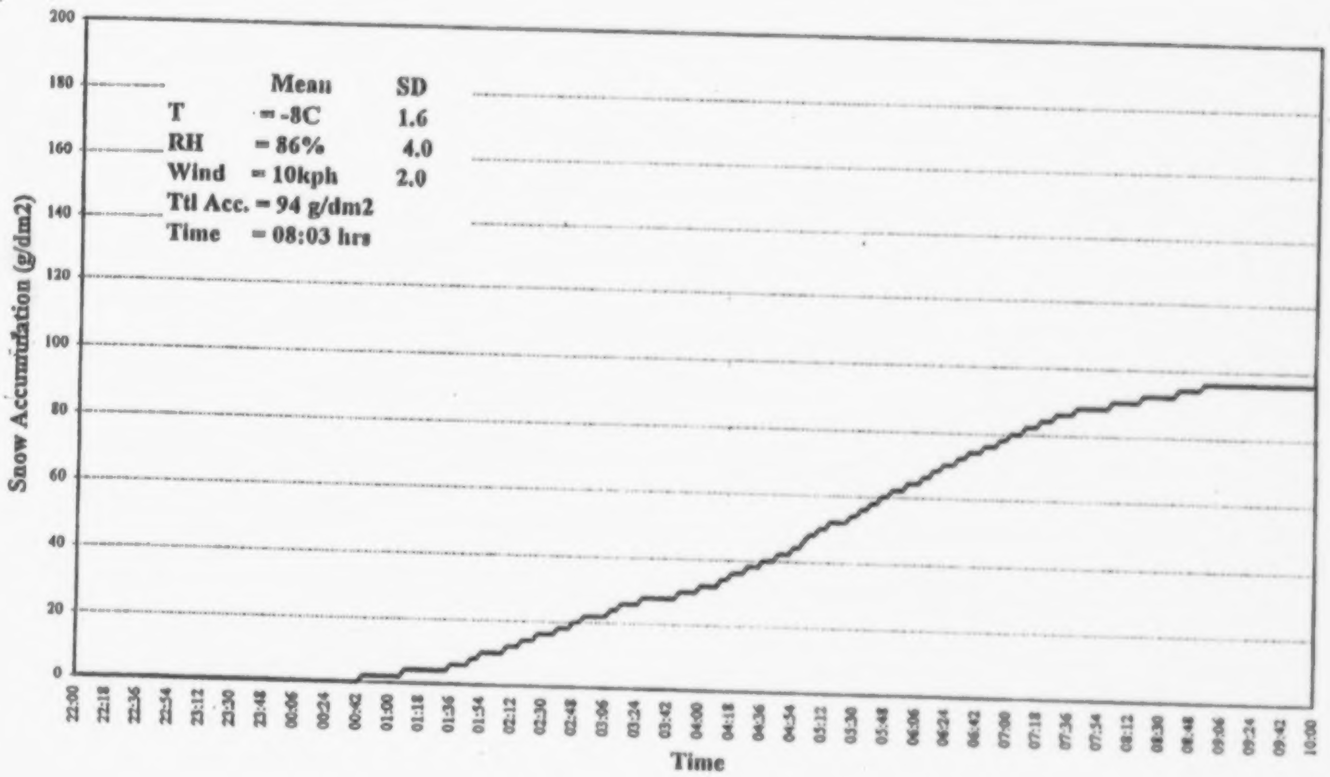
Total Snow Accumulation
for Jan. 27, 1993



14/8/95 15:26

JAN2794.XLS

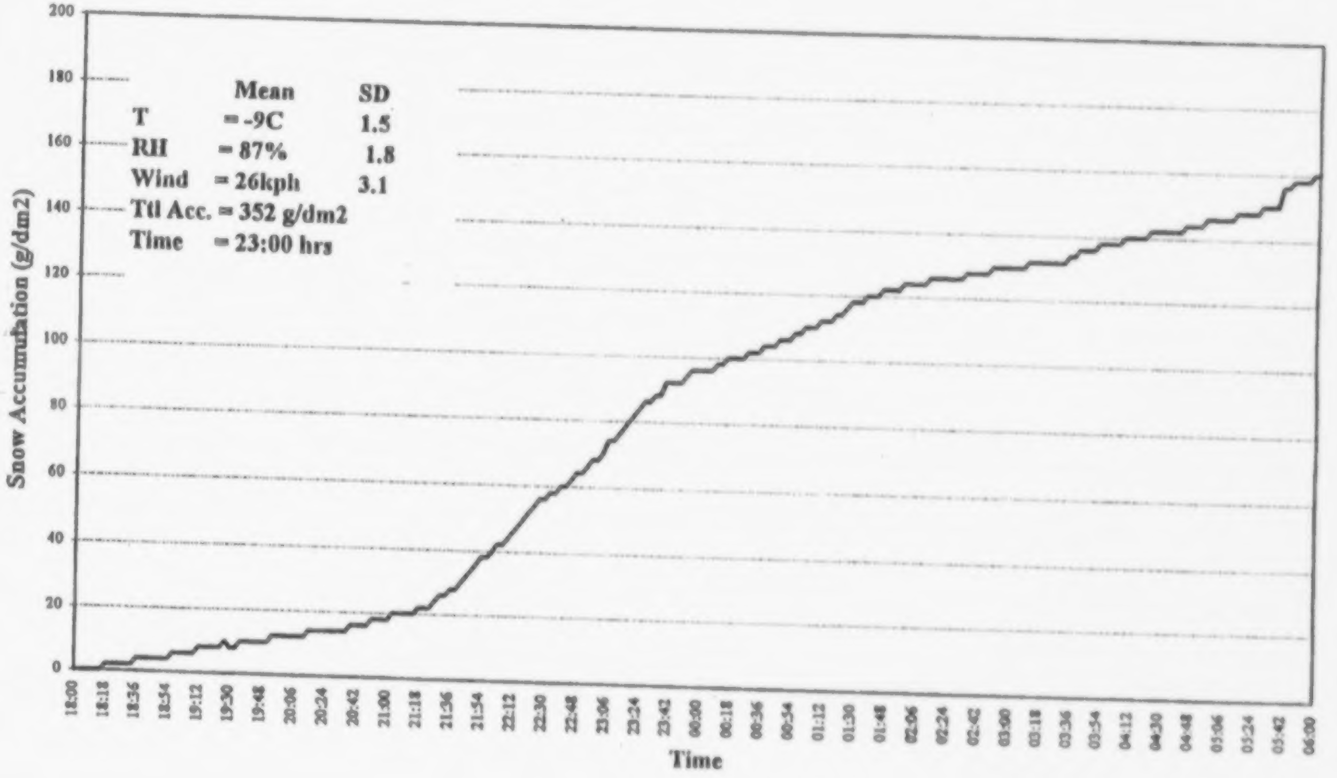
**Total Snow Accumulation**
**for Feb. 12-13, 1993**



14/8/95 15:34

FEB1294 XLS

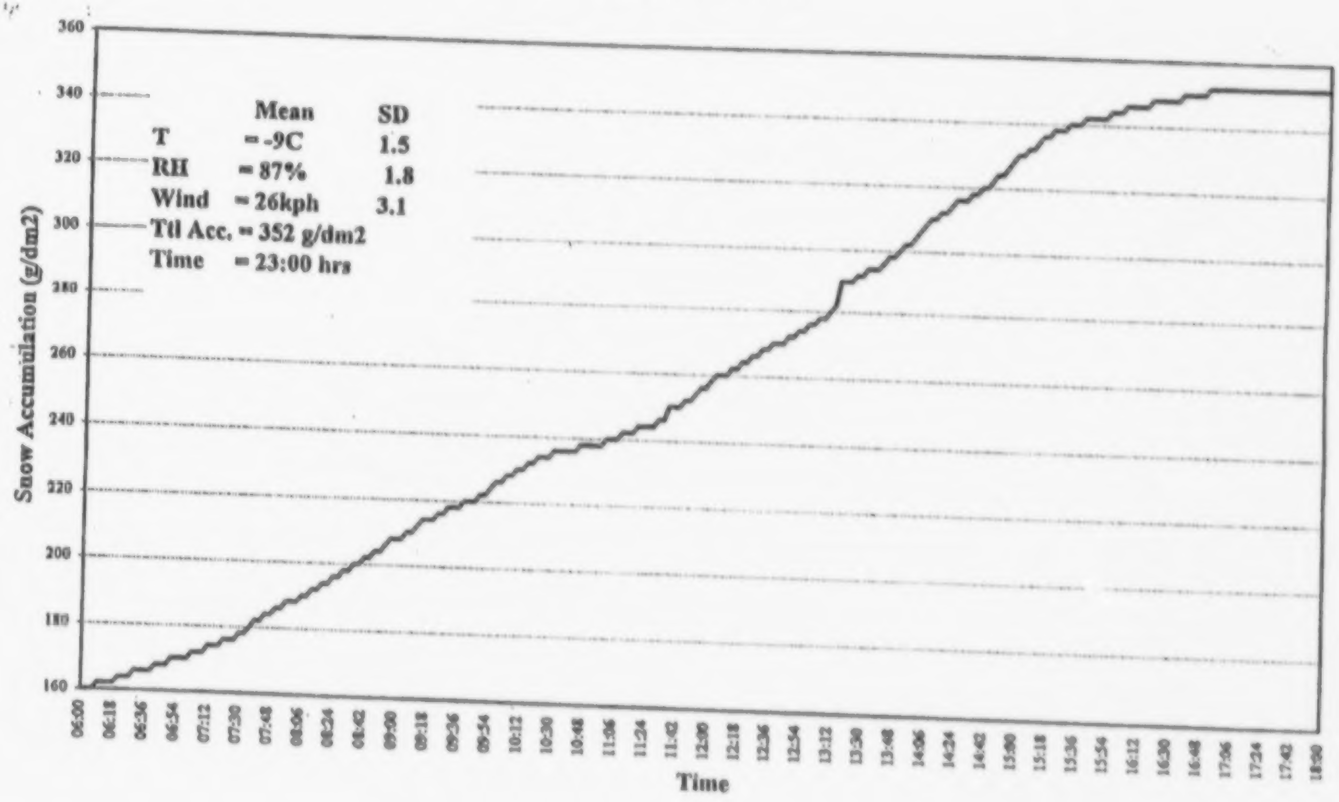
## Total Snow Accumulation for Feb 23-24, 1994



14/8/95 15:35

FEB2394.XLS

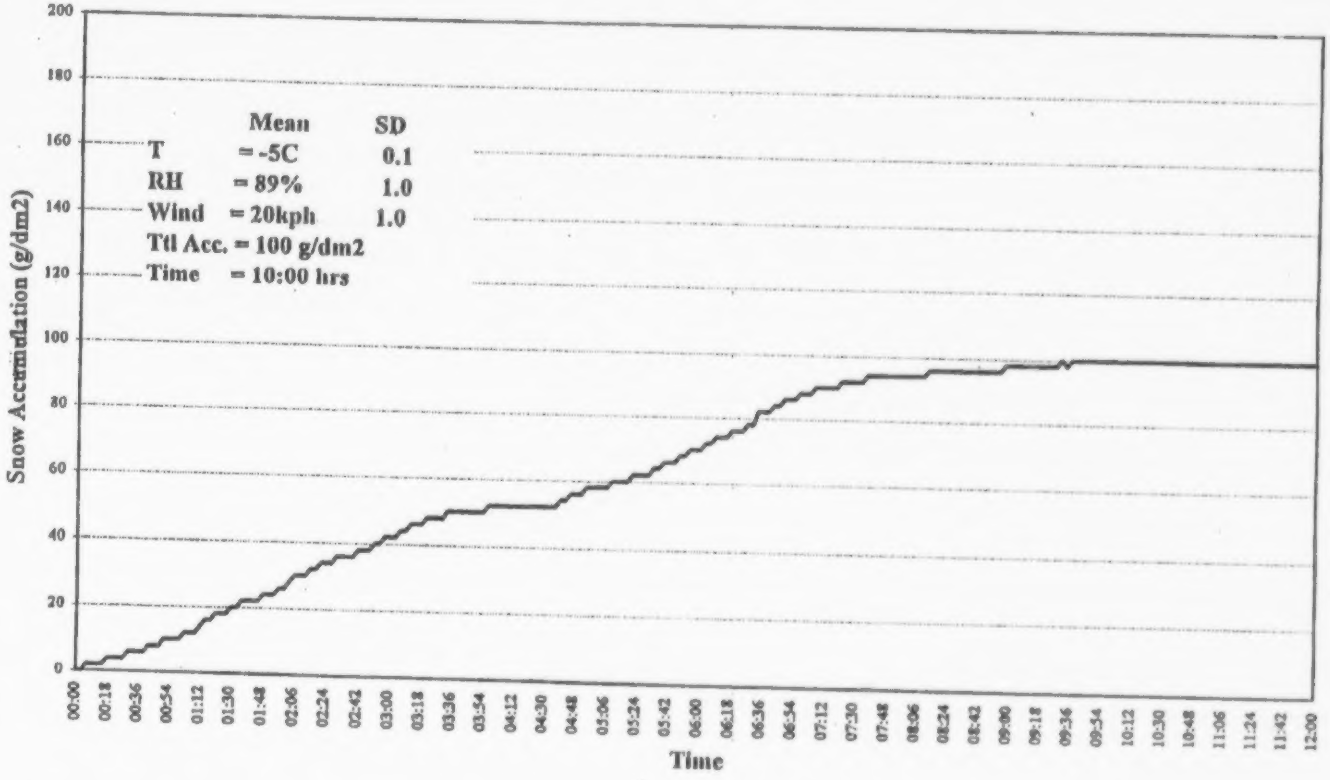
## Total Snow Accumulation
## for Feb 23-24, 1994



14/8/95 15:35

FED2394.XLS

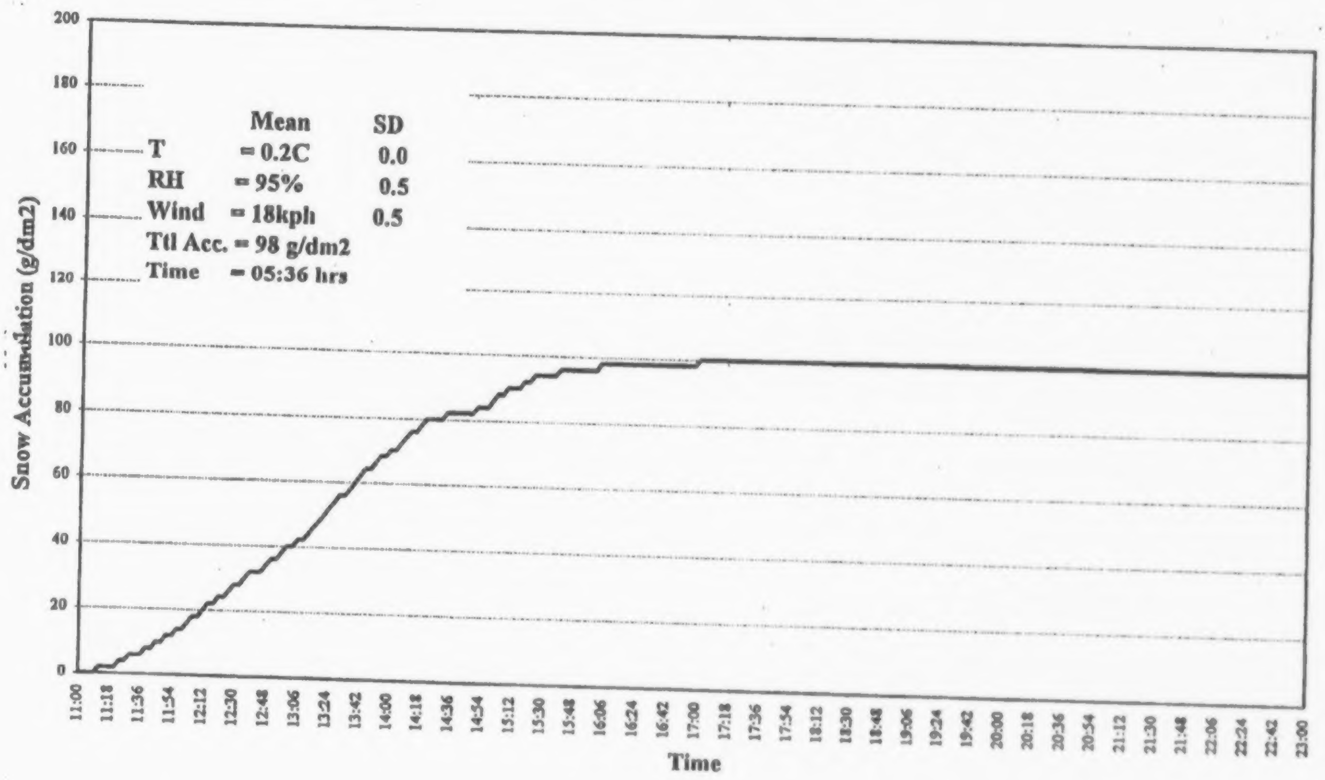
## Total Snow Accumulation
## for Mar. 10, 1994



14/8/95 15:37

MAR1094.XLS

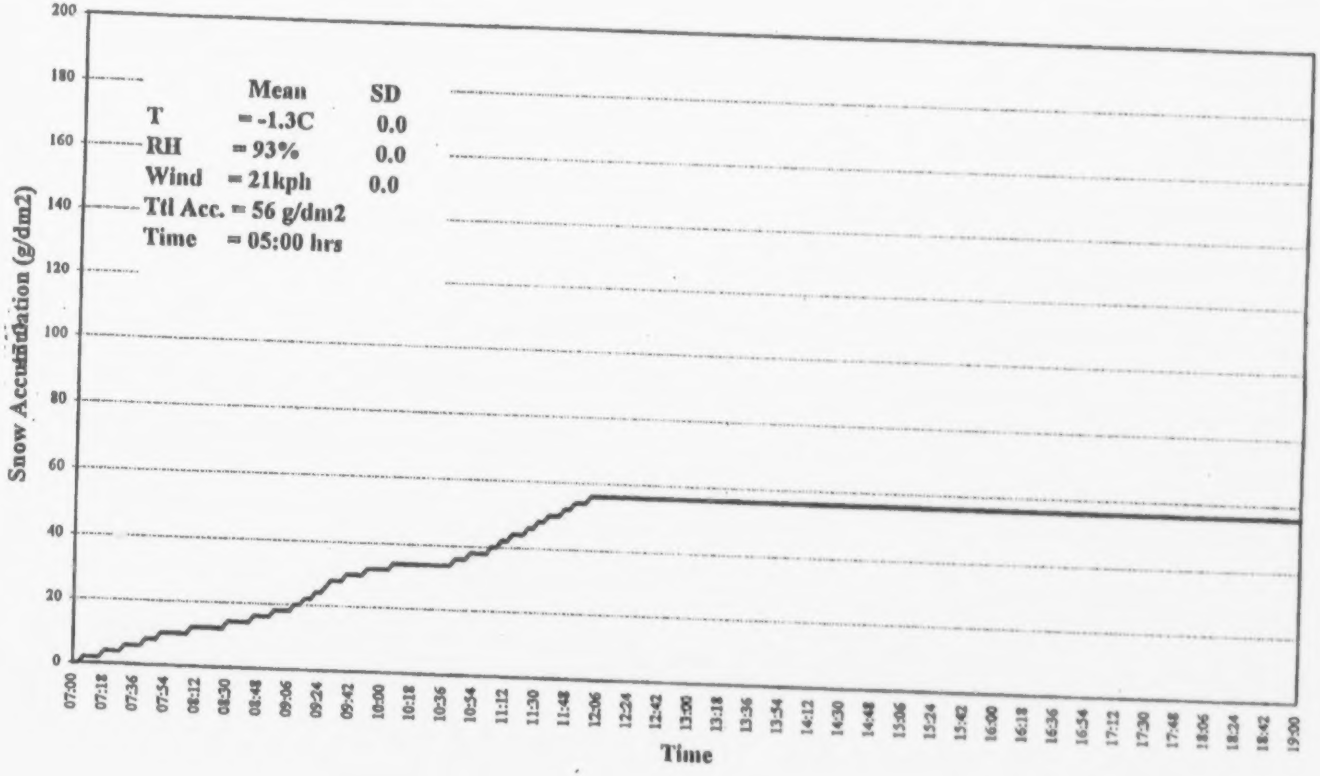
## Total Snow Accumulation
## for Mar. 27, 1994



14/8/95 15:36

MAR2794.XLS

## Total Snow Accumulation
## for Apr. 07, 1994



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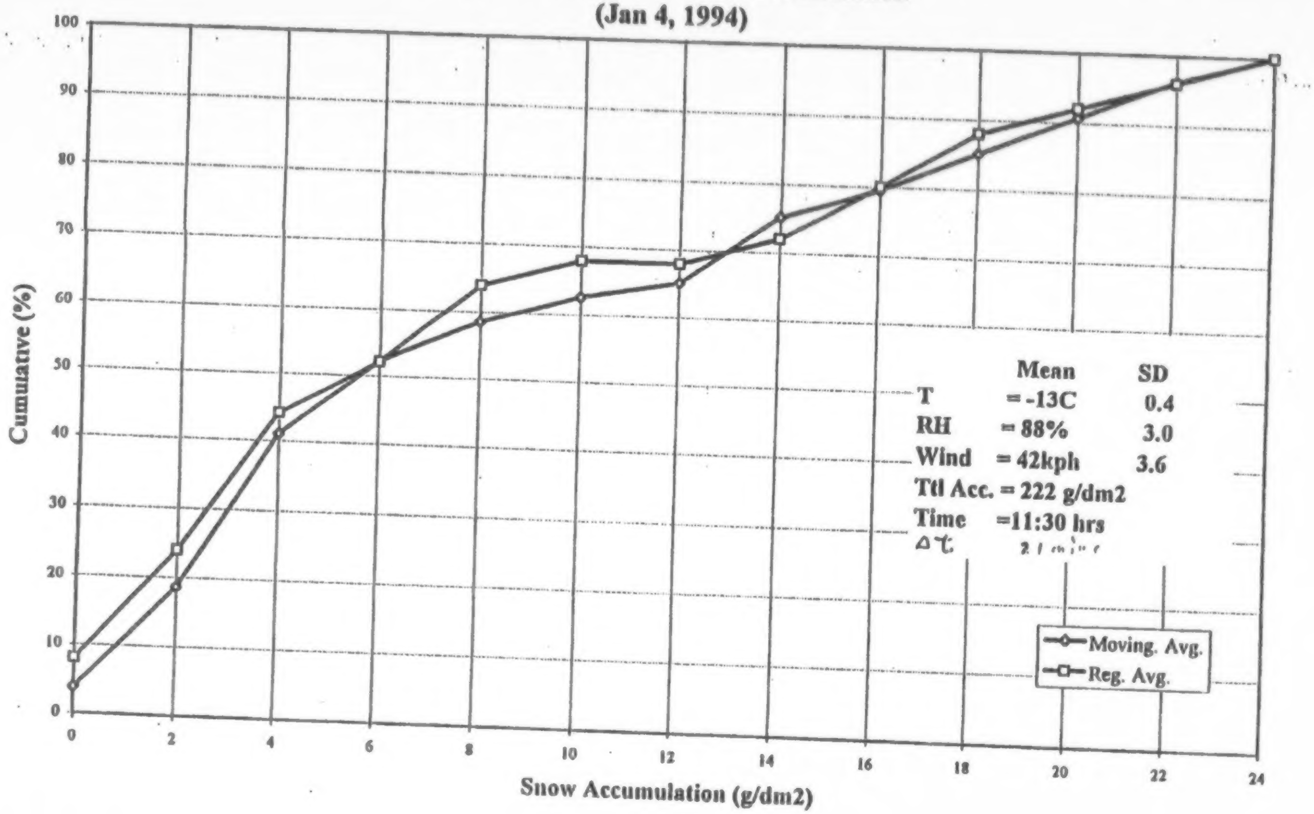
APR0794.XLS

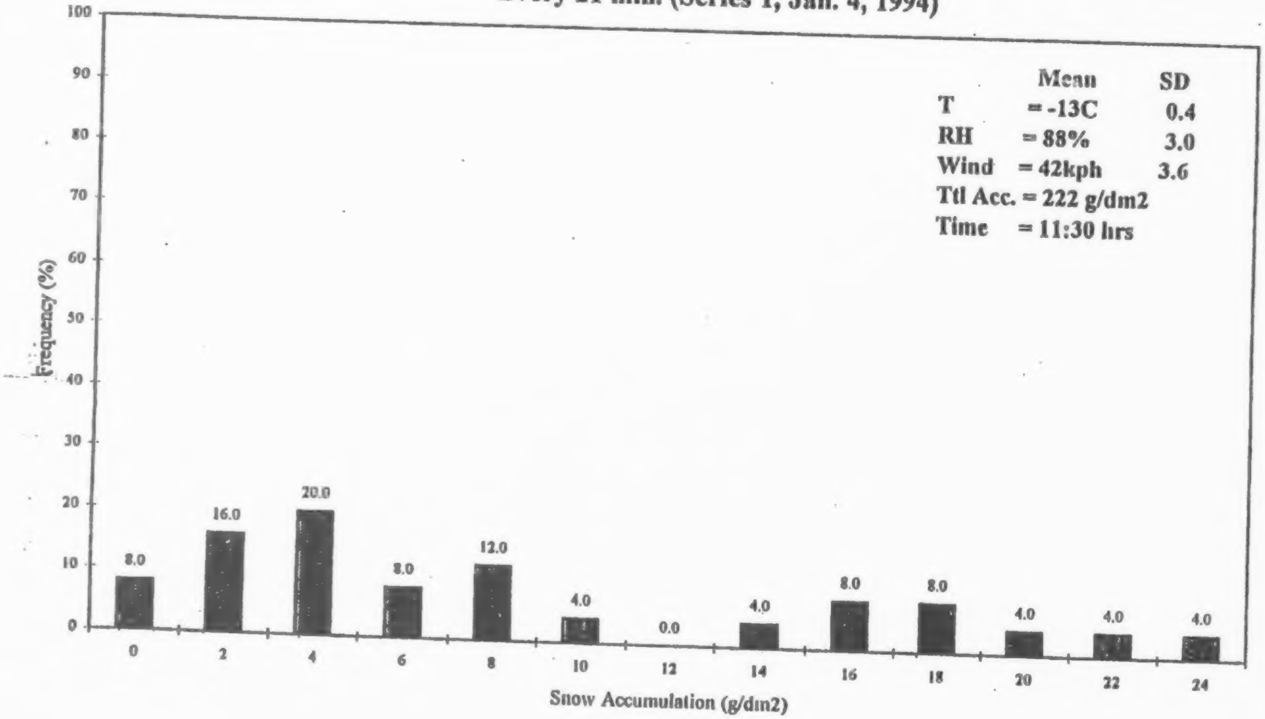
## Comparison Between Moving & Reg. Averages for Distribution for Snow Accumulation (Jan 4, 1994)



16/8/95 14:05

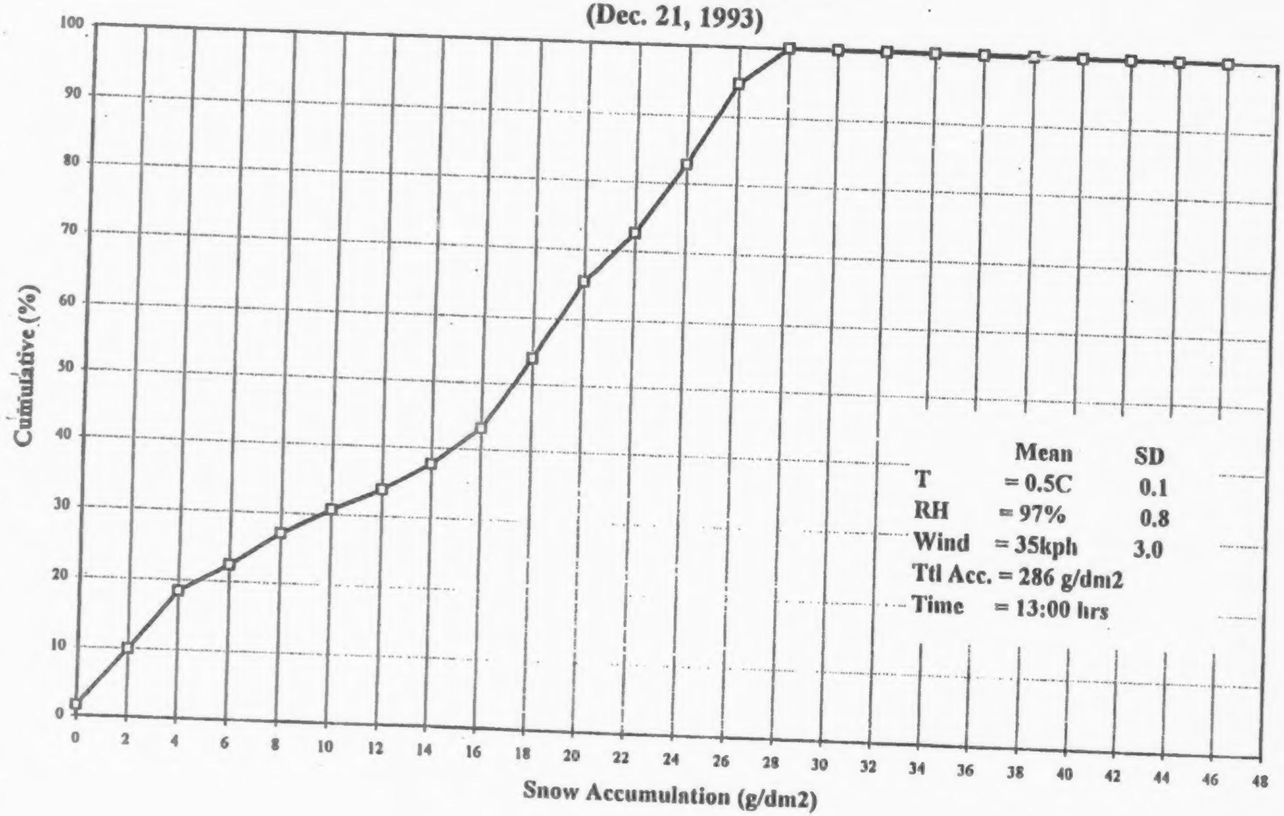
JAN0494.XLS

## Histogram for Snow Accumulation
Every 21 min. (Series 1, Jan. 4, 1994)



18/8/95 16:47

JAN0494.XLS

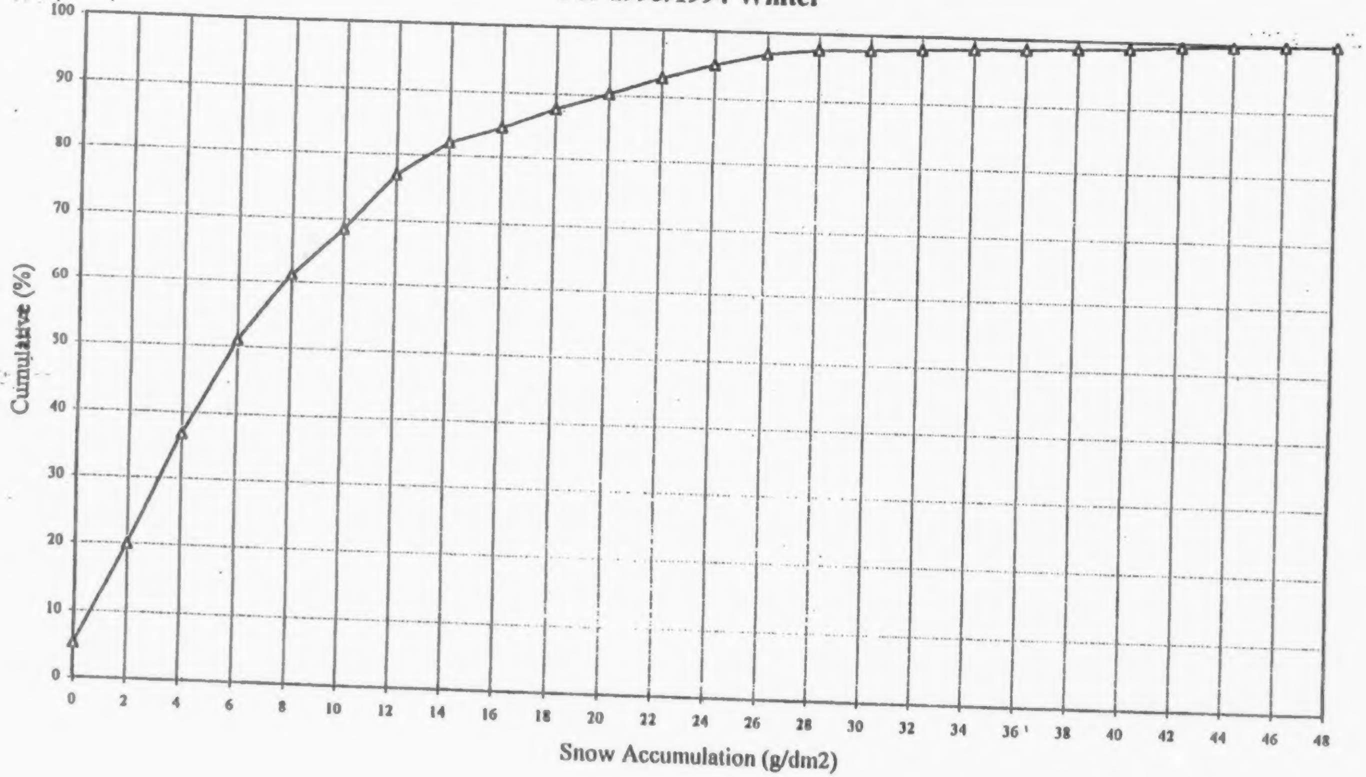


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Dec. 21, 1993)

18/8/95 16:17

DEC2193.XLS

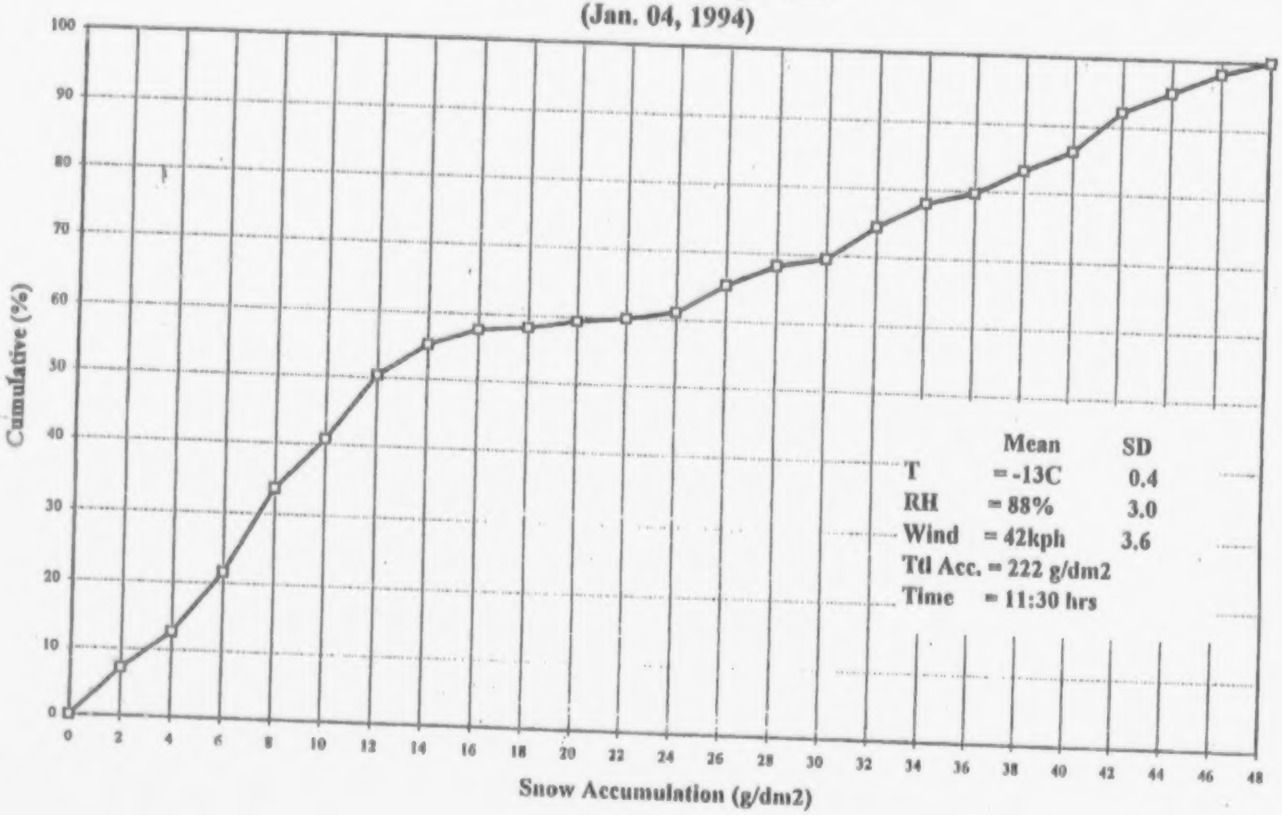
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/1994 Winter



18/8/95 15:29

MHIST94.XLS

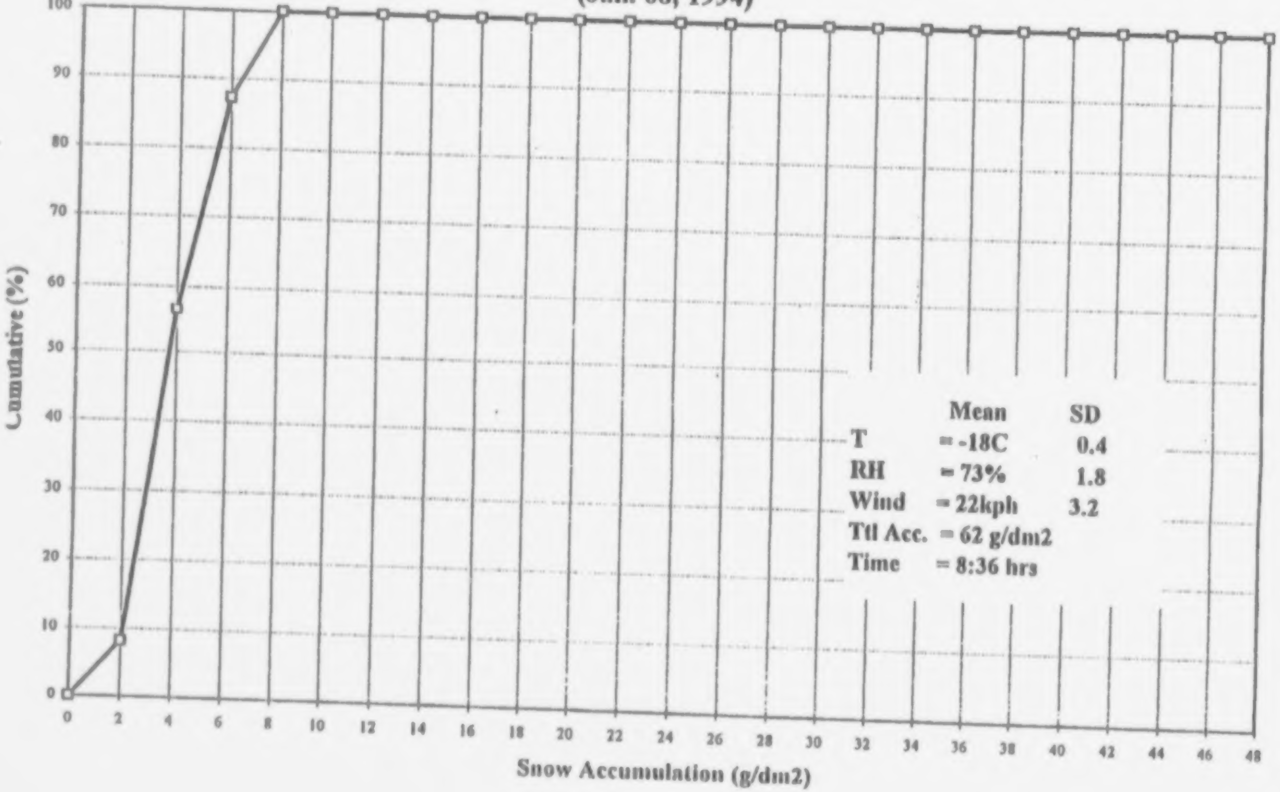
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 04, 1994)



18/8/95 16:24

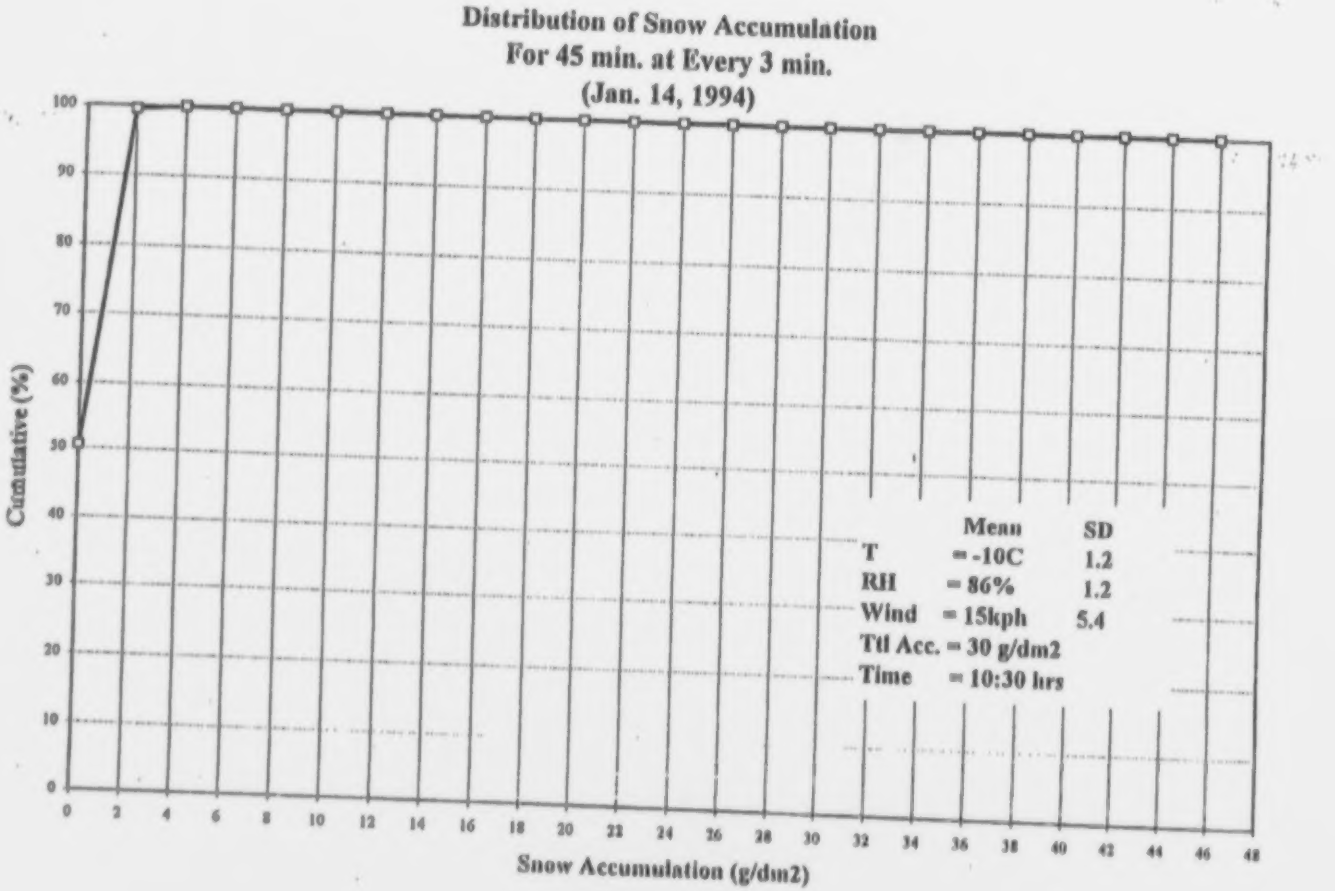
JAN0494.XLS

## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Jan. 08, 1994)



18/8/95 16:23

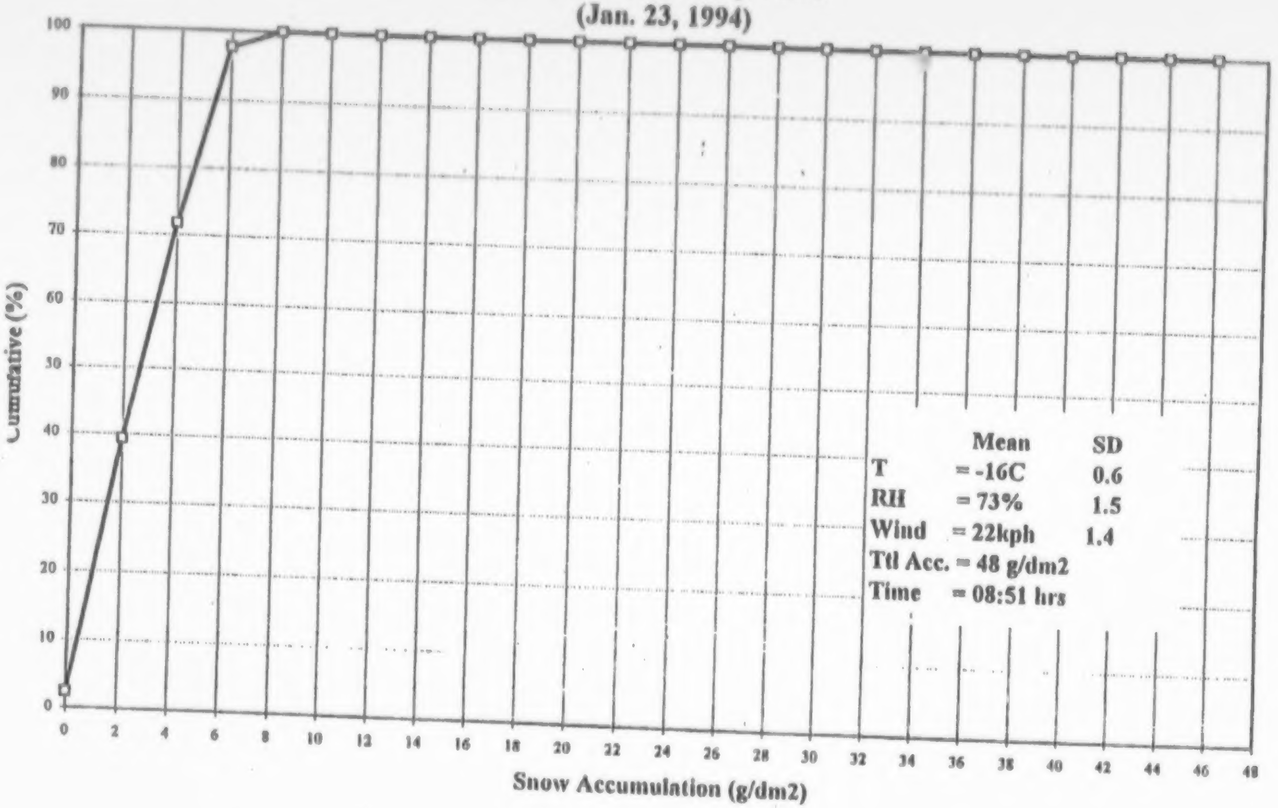
JAN0894.XLS



18/8/95 16:22

JAN1494.XLS

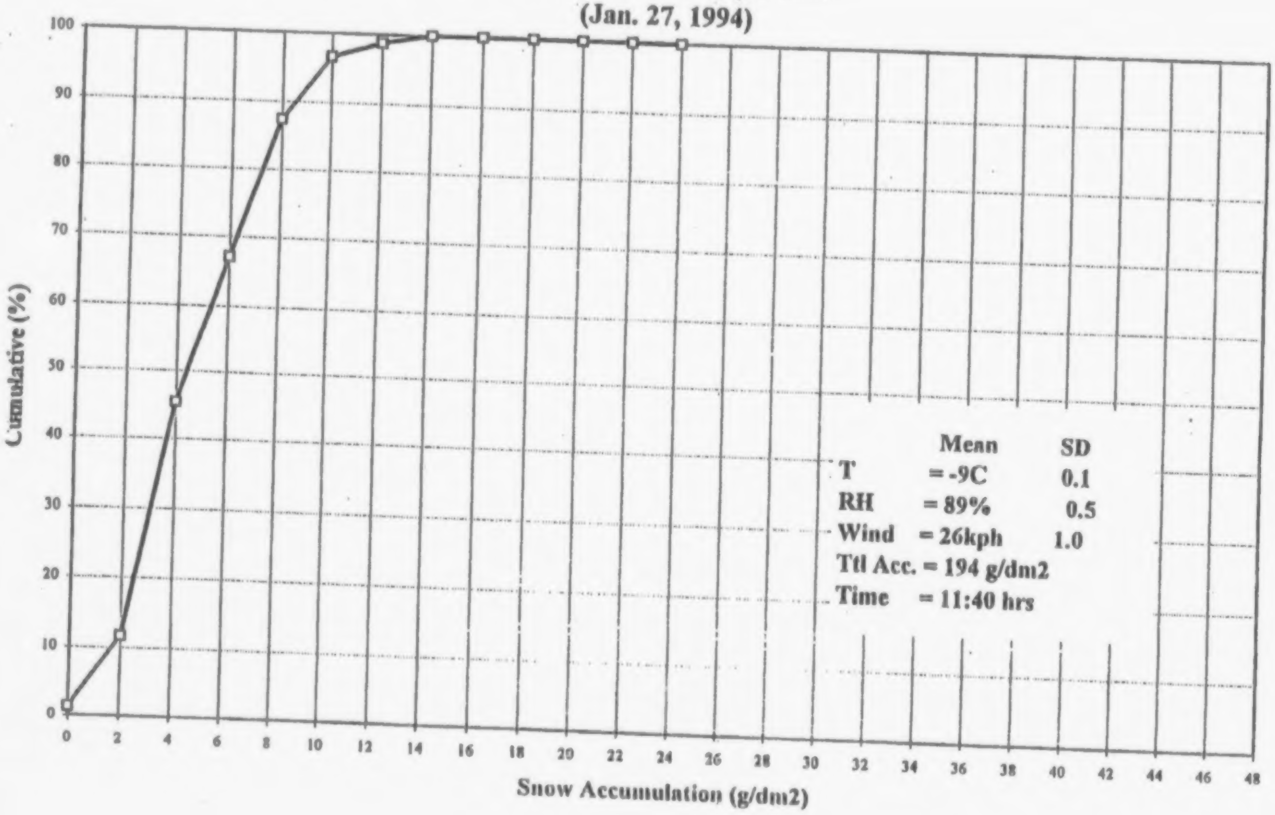
**Distribution of Snow Accumulation**
**For 45 min. at Every 3 min.**
**(Jan. 23, 1994)**



18/8/95 16:21

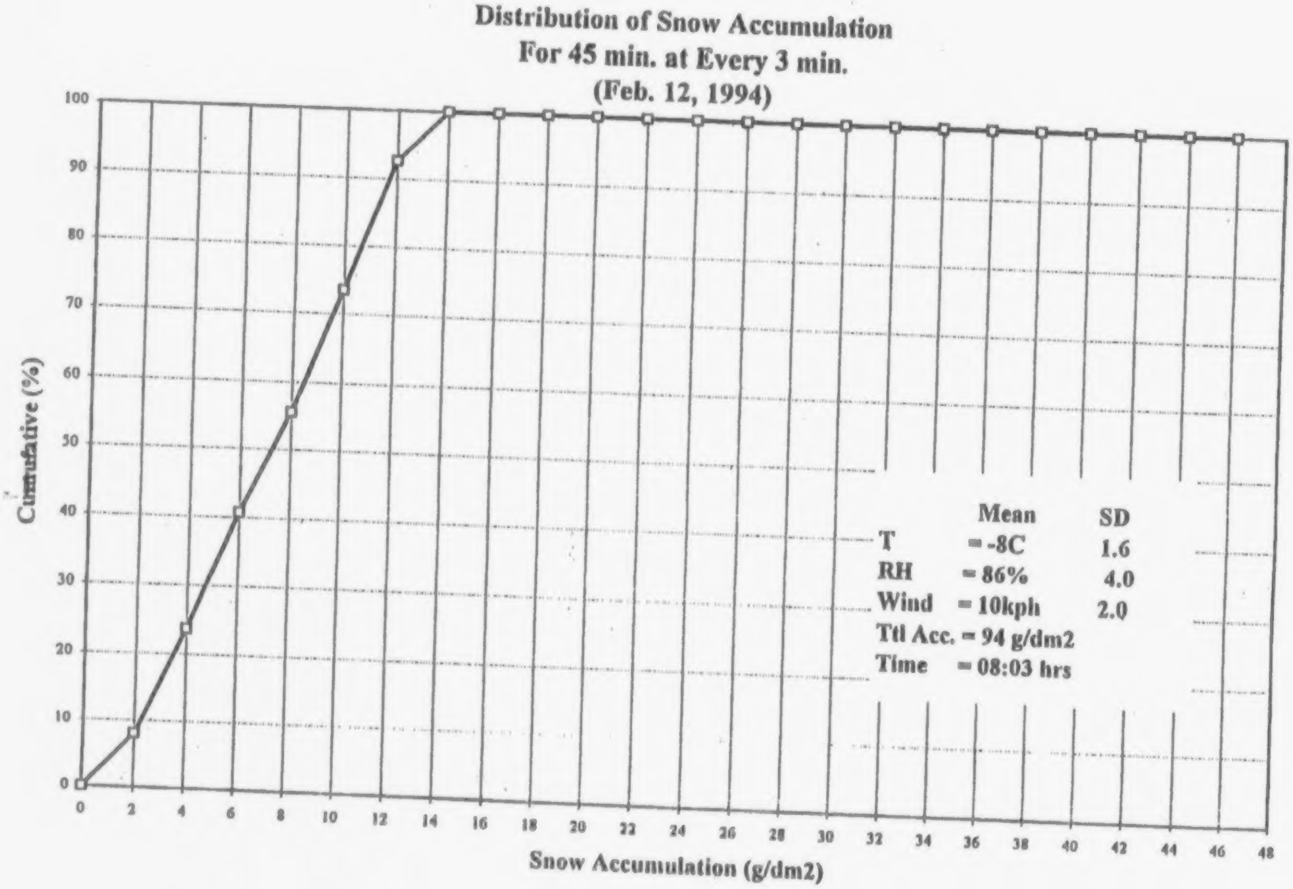
JAN2394.XLS

## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Jan. 27, 1994)



18/8/95 16:20

JAN2794.XLS

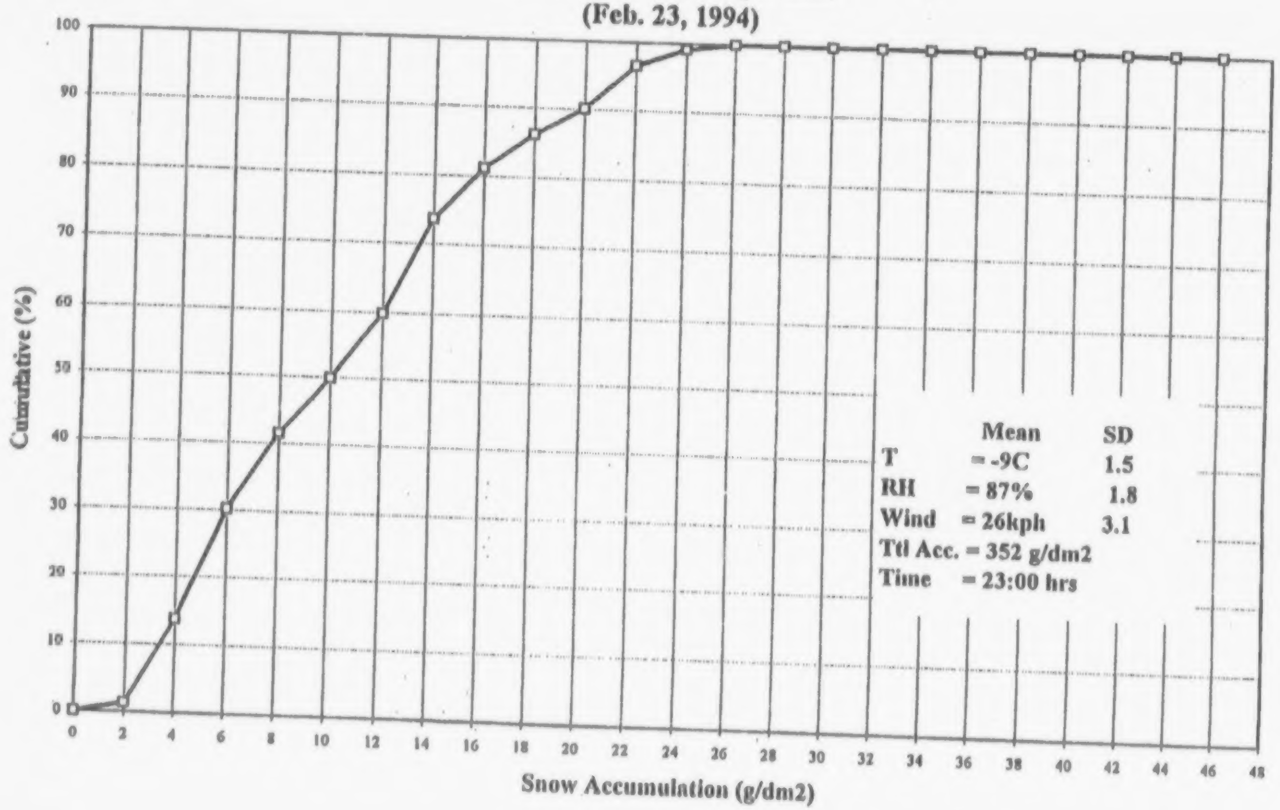


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 12, 1994)

| | Mean | SD |
|---|---|---|
| T | = -8C | 1.6 |
| RH | = 86% | 4.0 |
| Wind | = 10kph | 2.0 |
| Ttl Acc. | = 94 g/dm2 | |
| Time | = 08:03 hrs | |

18/8/95 16:28

FEB1294.XLS

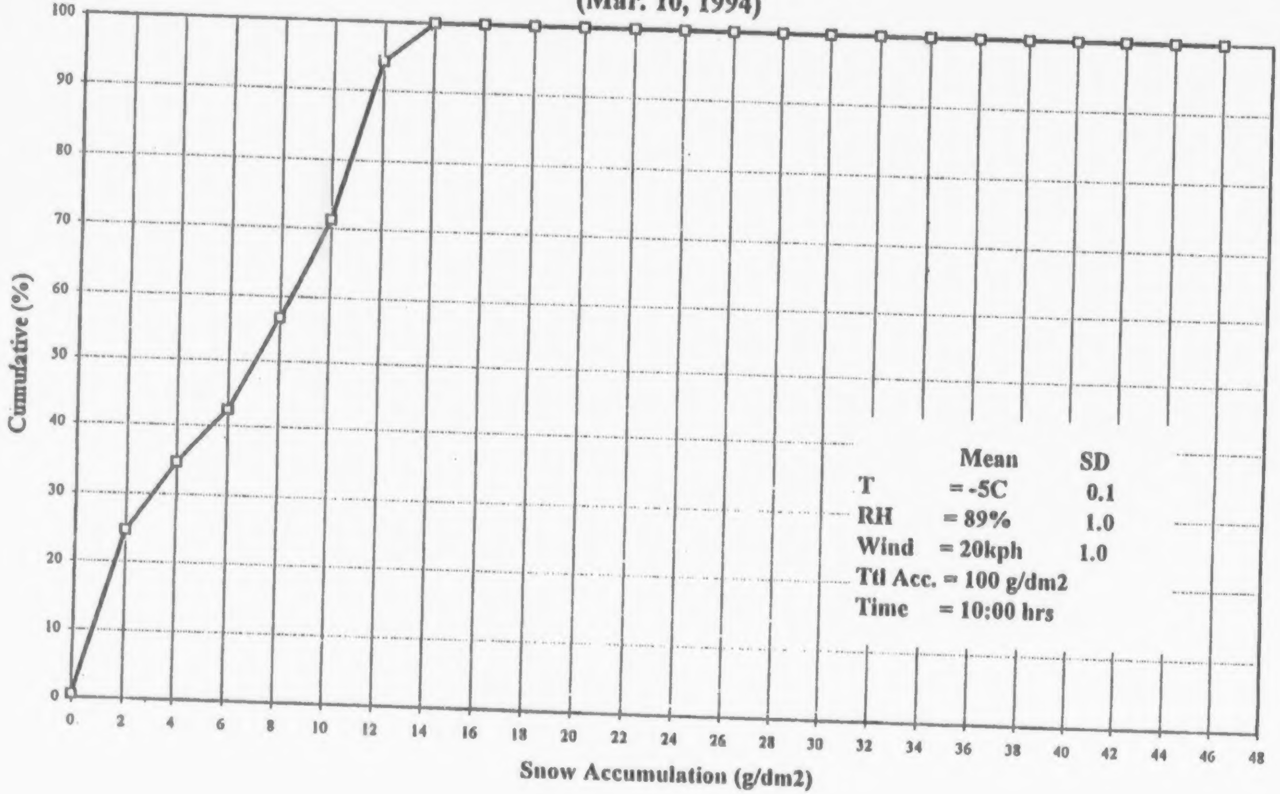


Distribution for Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 23, 1994)

18/8/95 16:27

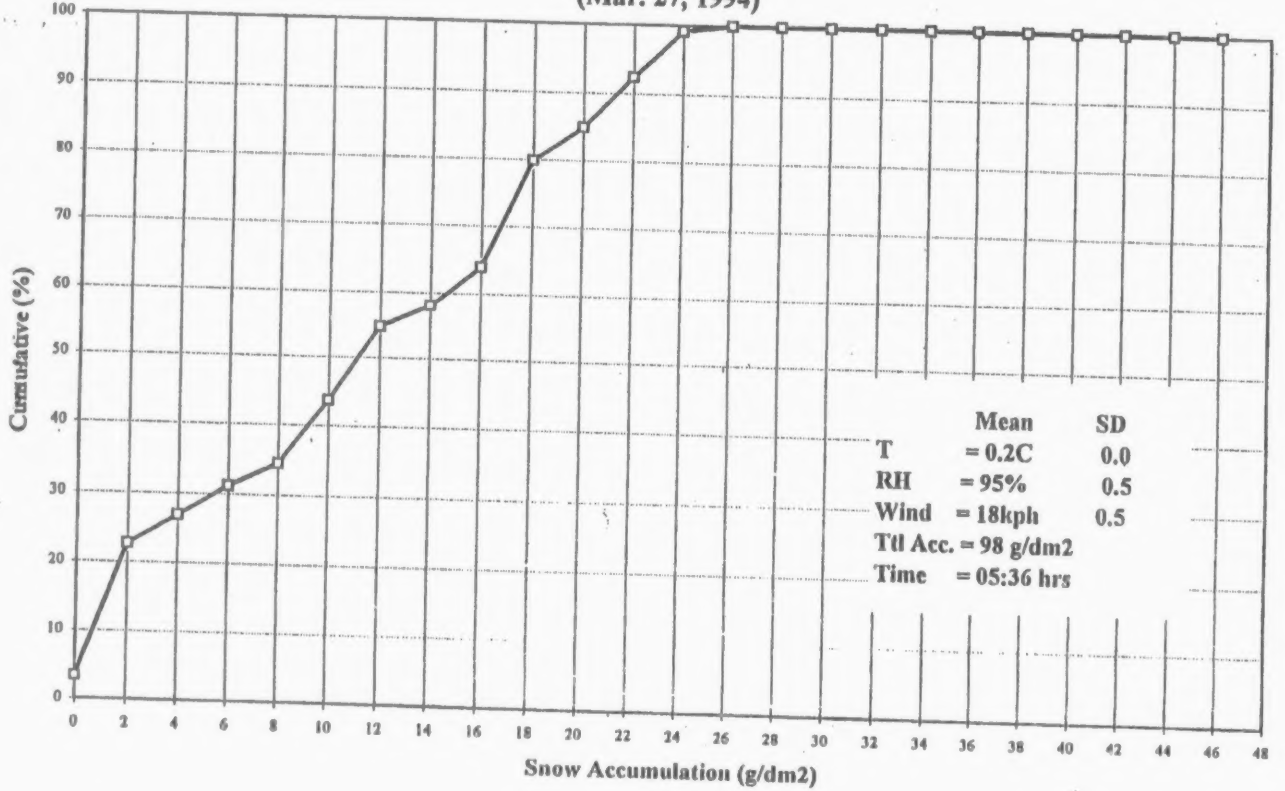
FEB2394.XLS

## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Mar. 10, 1994)



18/8/95 16:31

MAR1094.XLS

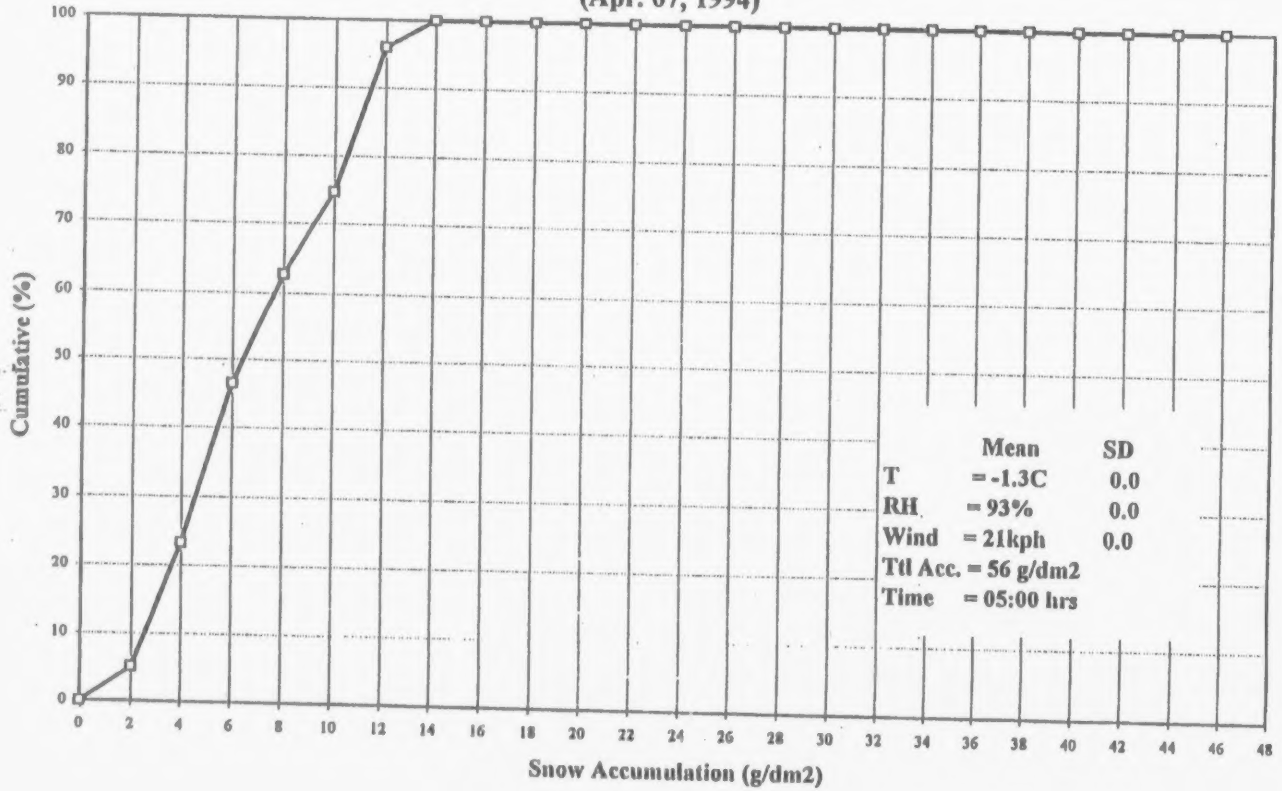


**Distribution of Snow Accumulation**
**For 45 min. at Every 3 min.**
**(Mar. 27, 1994)**

18/8/95 16:30

MAR2794.XLS

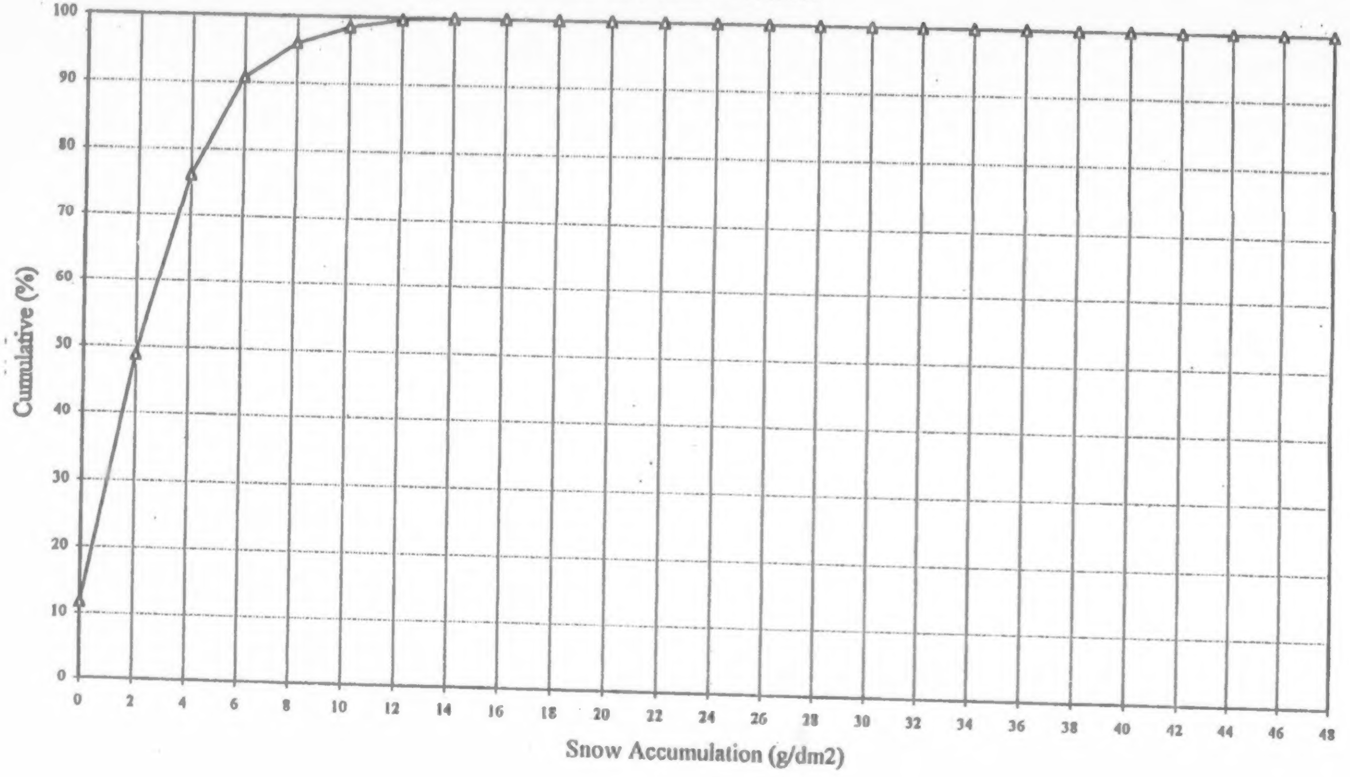
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Apr. 07, 1994)



18/8/95 16:33

APR0794.XLS

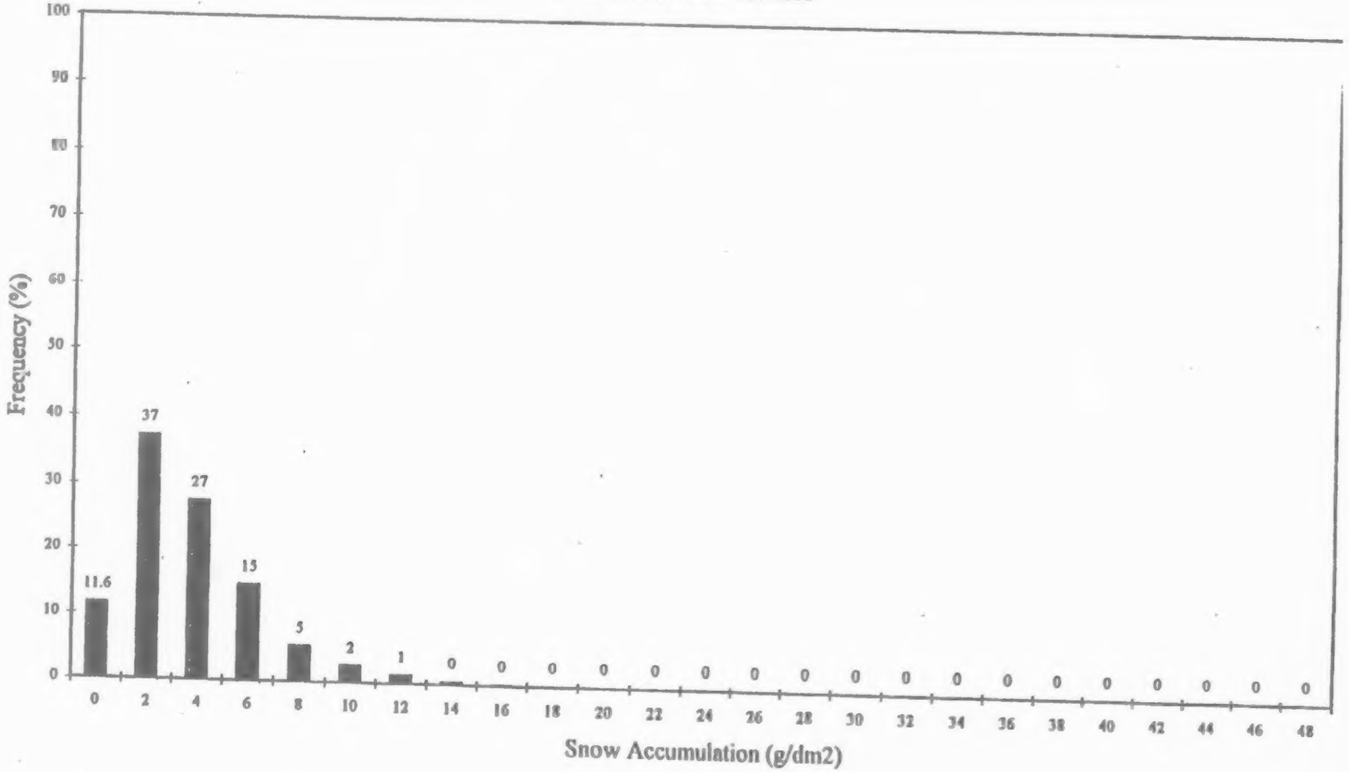
**Distribution for Snow Accumulation**
**For 21 min. at Every 3 min.**
**For 1994/1995 Winter**



18/8/95 15:25

MHIST95.XL

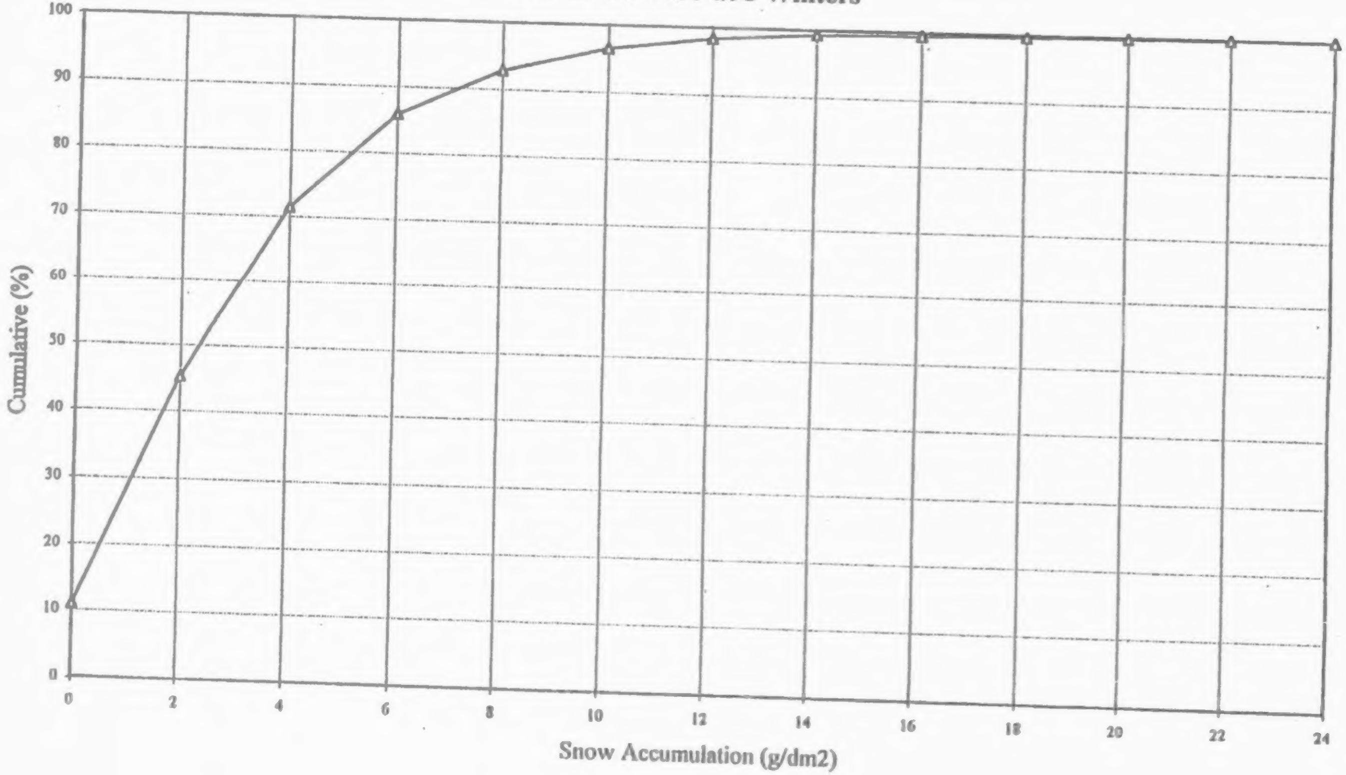
## Histogram for Snow Accumulation
## For 21 min. at Every 3 min.
## For 1994/1995 Winter



18/8/95 11:36

MHIST95.XL

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters



18/8/95 15:25

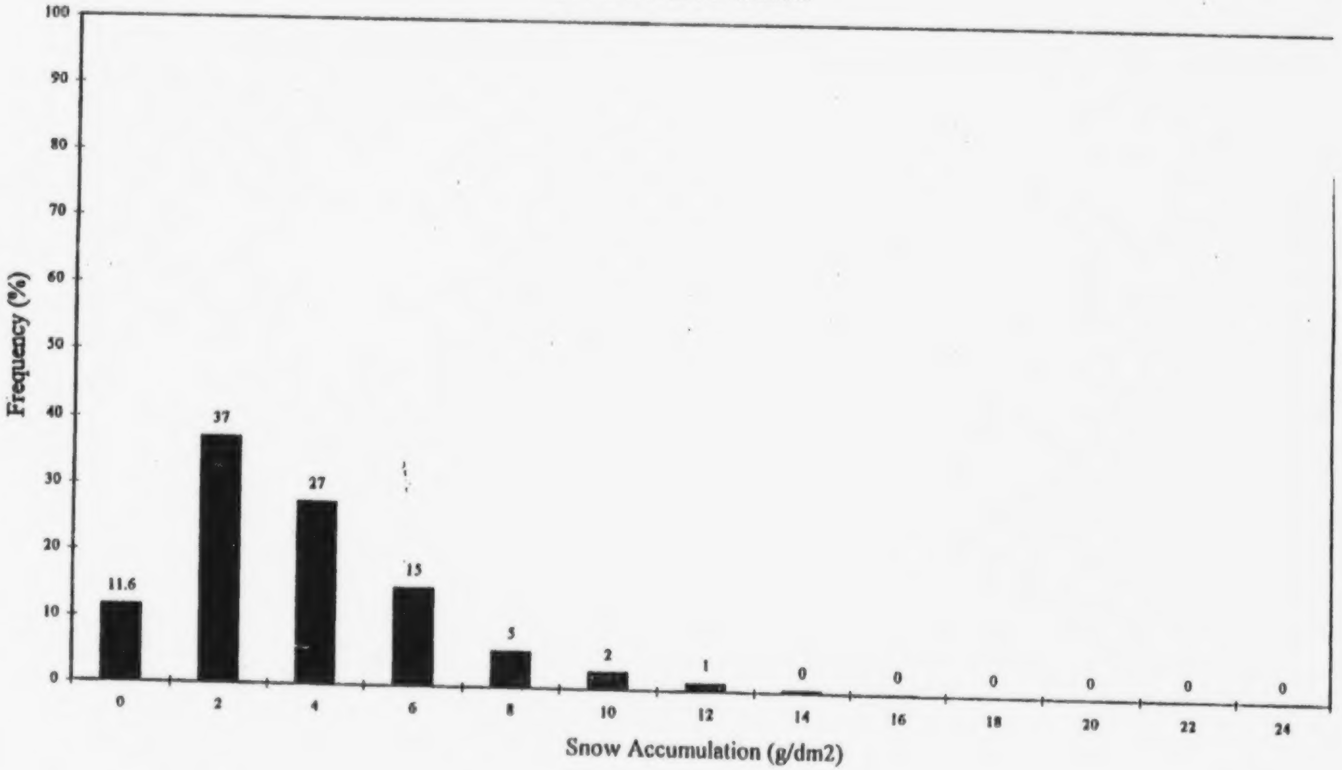
MHIST95.XL

MAVG95

## MOVING AVERAGE
## 1994/1995

| RANGE | 950107 | 950112 | 950204 | 950211 | 950216 | 950224 | 950227 | 950306 | 950308A | 950308B | 950308C | SUM | % | CUMUL. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 100 | 16 | 116 | 123 | 0 | 85 | 44 | 23 | 0 | 0 | 3 | 510 | 11.6 | 11.6 |
| 1 | 76 | 86 | 117 | 118 | 7 | 41 | 101 | 93 | 3 | 40 | 58 | 740 | 16.8 | 28.4 |
| 2 | 108 | 115 | 34 | 129 | 14 | 151 | 121 | 14 | 12 | 26 | 164 | 888 | 20.2 | 48.6 |
| 3 | 74 | 91 | 26 | 53 | 53 | 36 | 152 | 13 | 22 | 31 | 83 | 634 | 14.4 | 63.1 |
| 4 | 78 | 77 | 13 | 47 | 67 | 29 | 121 | 17 | 6 | 6 | 109 | 570 | 13.0 | 76.0 |
| 5 | 56 | 45 | 0 | 17 | 43 | 6 | 48 | 32 | 1 | 17 | 129 | 394 | 9.0 | 85.0 |
| 6 | 61 | 11 | 0 | 16 | 46 | 9 | 4 | 26 | 8 | 18 | 51 | 250 | 5.7 | 90.7 |
| 7 | 6 | 25 | 0 | 9 | 34 | 0 | 1 | 36 | 3 | 17 | 28 | 159 | 3.6 | 94.3 |
| 8 | 5 | 13 | 0 | 2 | 24 | 0 | 0 | 13 | 6 | 11 | 1 | 75 | 1.7 | 96.0 |
| 9 | 0 | 6 | 0 | 0 | 11 | 0 | 0 | 20 | 13 | 15 | 0 | 65 | 1.5 | 97.5 |
| 10 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 10 | 5 | 10 | 0 | 43 | 1.0 | 98.5 |
| 11 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 7 | 15 | 4 | 0 | 33 | 0.8 | 99.2 |
| 12 | 0 | 1 | 0 | 0 | 6 | 0 | 0 | 2 | 8 | 1 | 0 | 18 | 0.4 | 99.6 |
| 13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 4 | 0 | 9 | 0.2 | 99.8 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 6 | 0.1 | 100.0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0.0 | 100.0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 100.0 |
|  |  |  |  |  |  |  |  |  |  |  |  | 4396 |  |  |

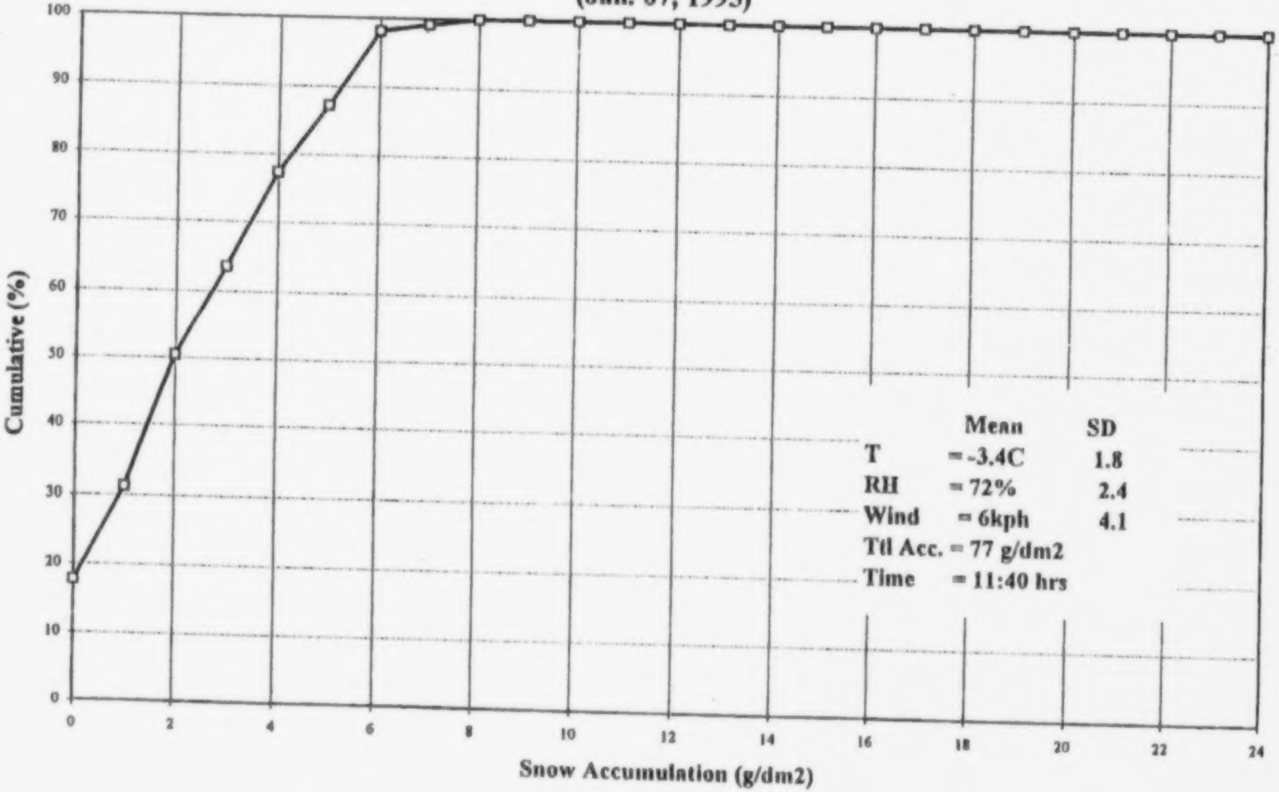
Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994/1995 Winter



17/8/95 11:48

MHIST95.XL

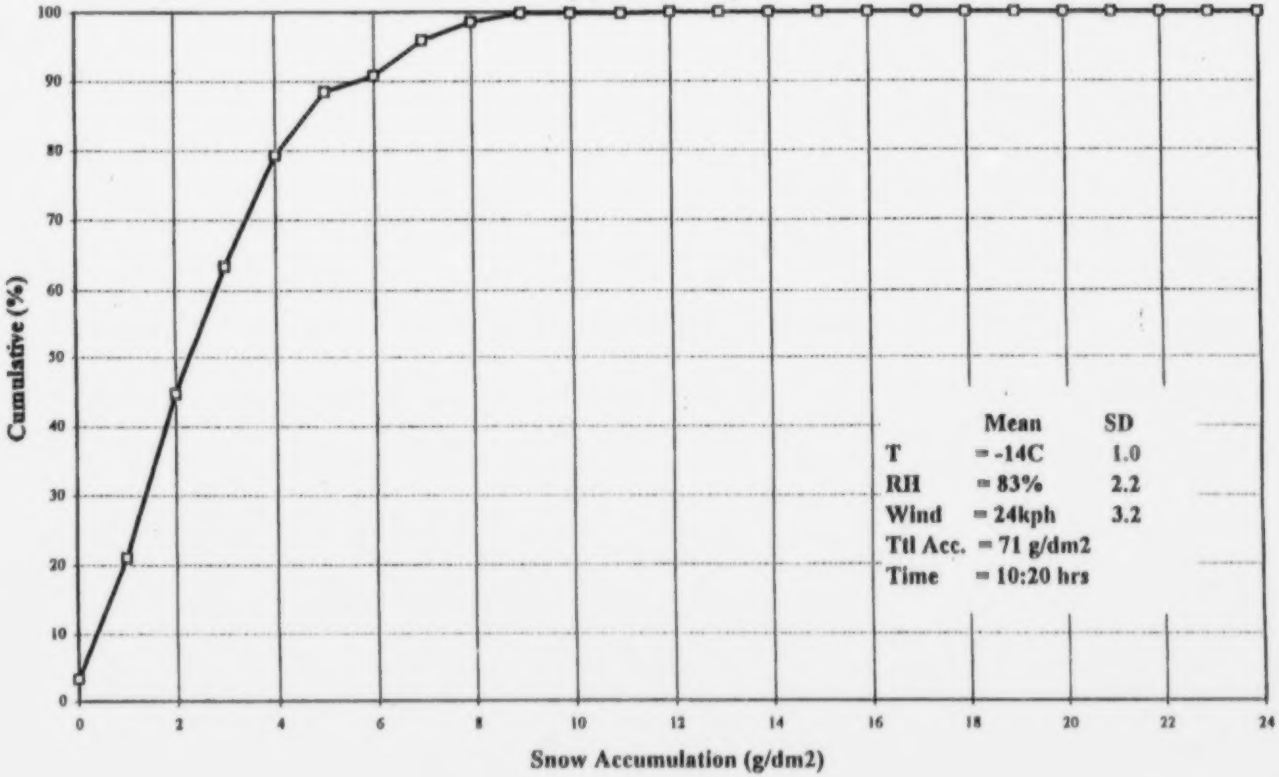
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 07, 1995)



17/8/95 13:23

950107.XLS

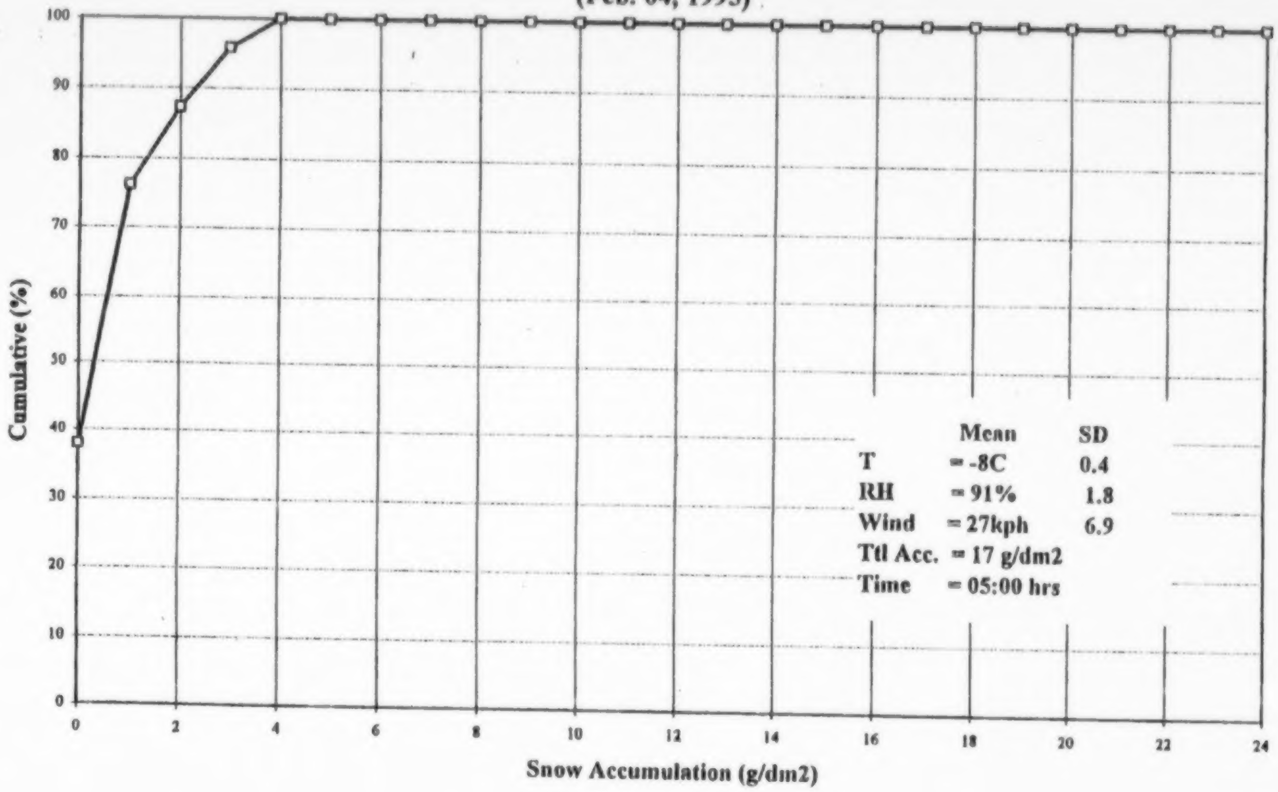
For 21 min. at Every 3 min.
(Jan. 12, 1995)



18/8/95 15:34

950112.XLS

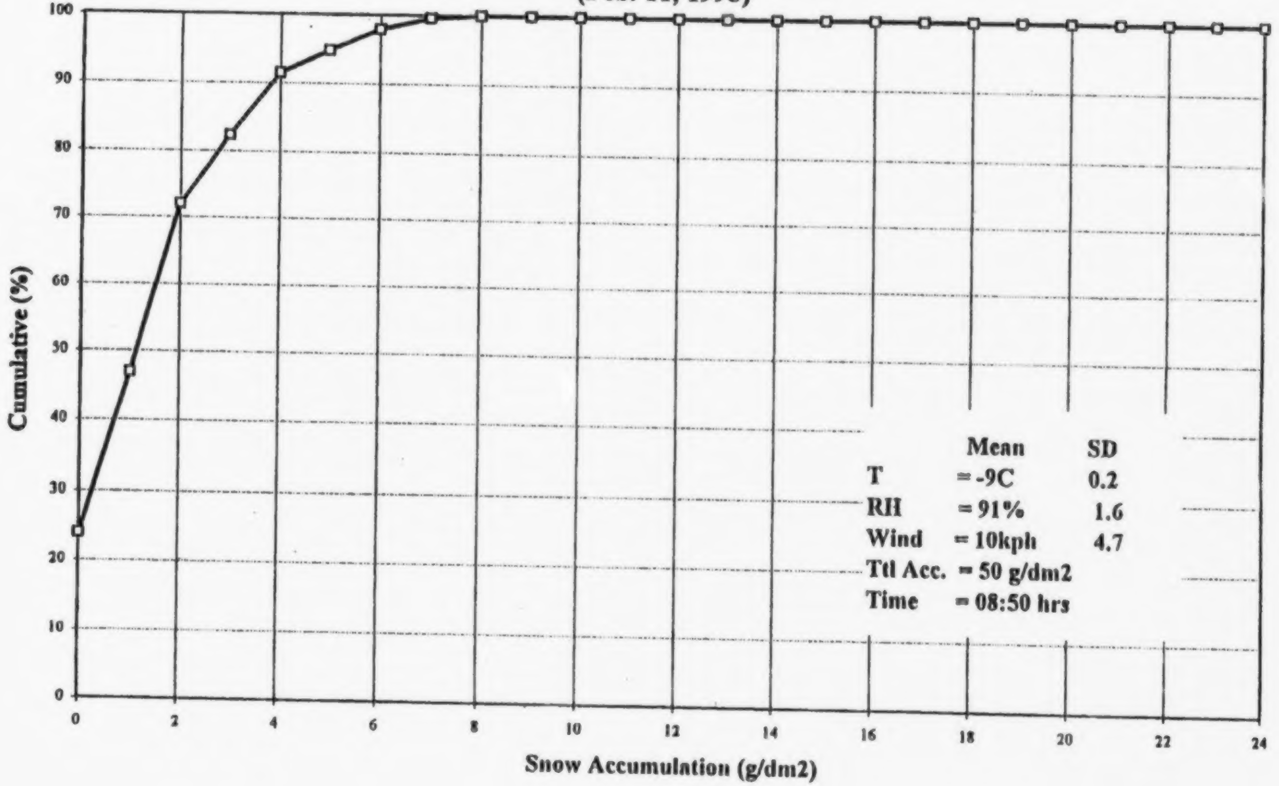
## Distribution of Snow Accumulation
## For 21 min. at Every 3 min.
## (Feb. 04, 1995)



17/8/95 13:29

950204.XLS

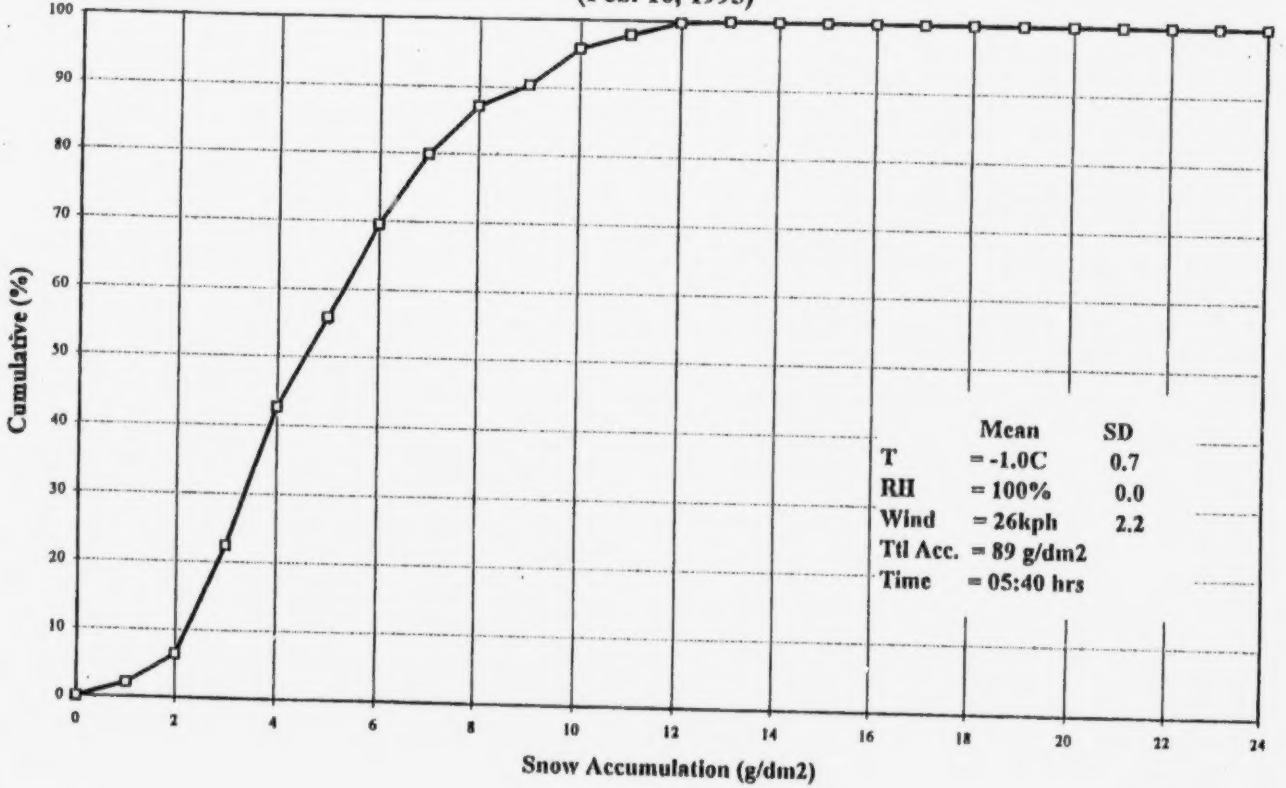
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Feb. 11, 1995)**



17/8/95 13:32

950211.XLS

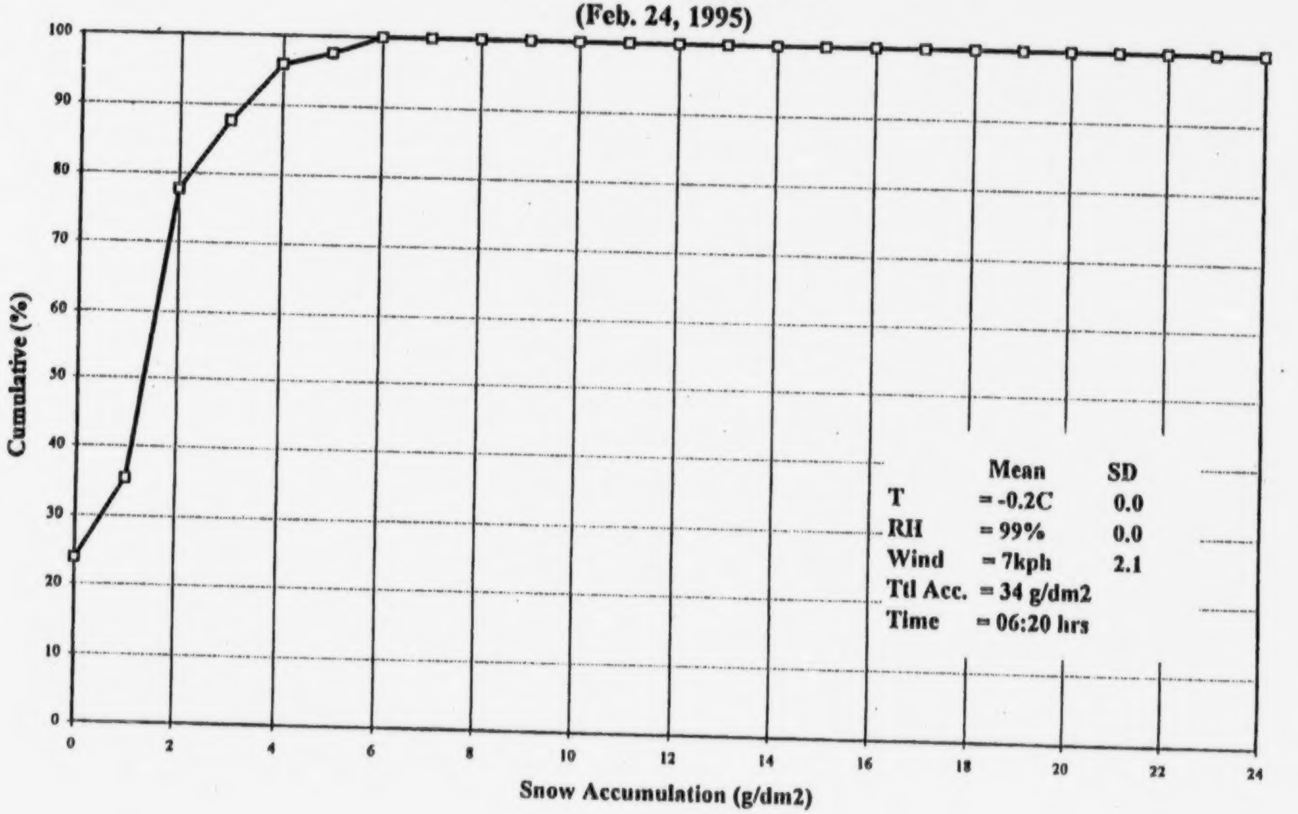
### Distribution of Snow Accumulation
### For 21 min. at Every 3 min.
### (Feb. 16, 1995)



17/8/95 13:32

950216.XLS

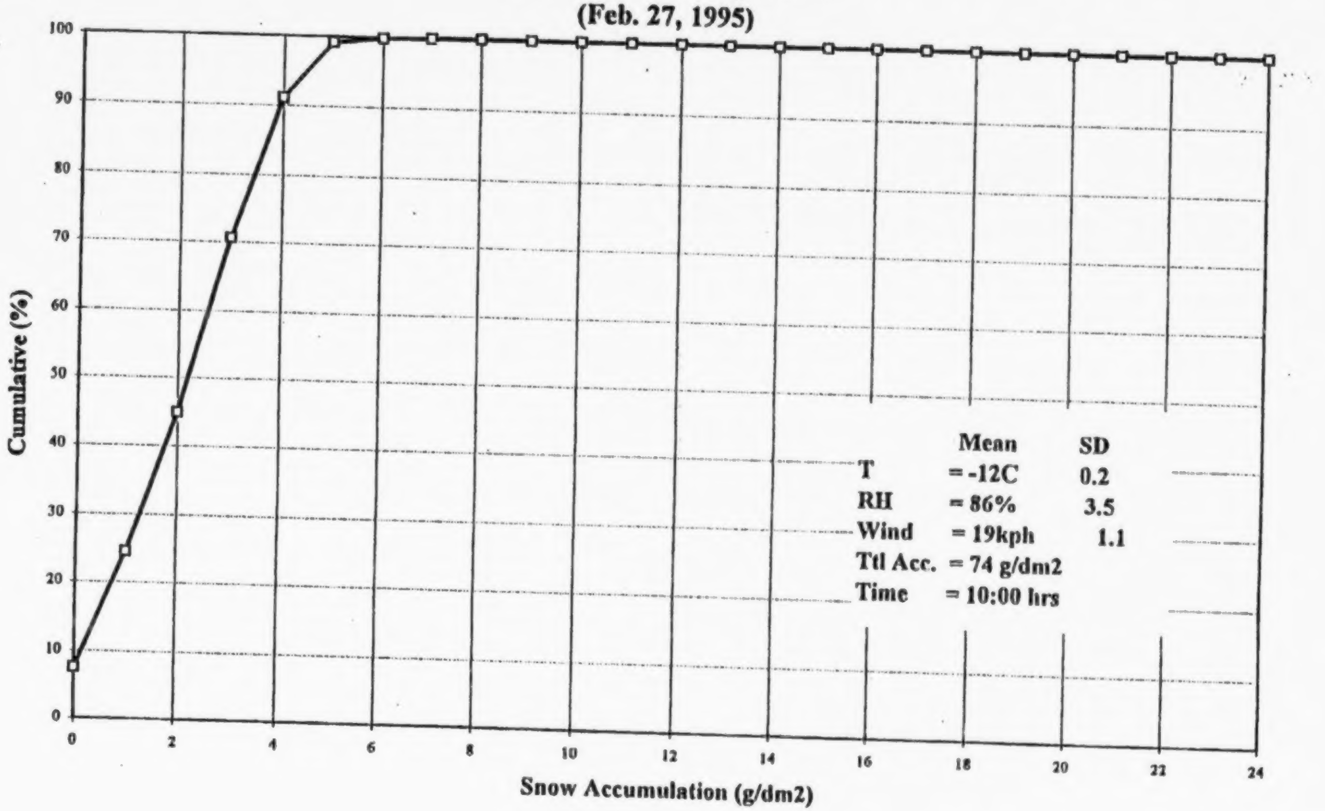
## Distribution of Snow Accumulation For 21 min. at Every 3 min. (Feb. 24, 1995)



17/8/95 13:37

950224.XL

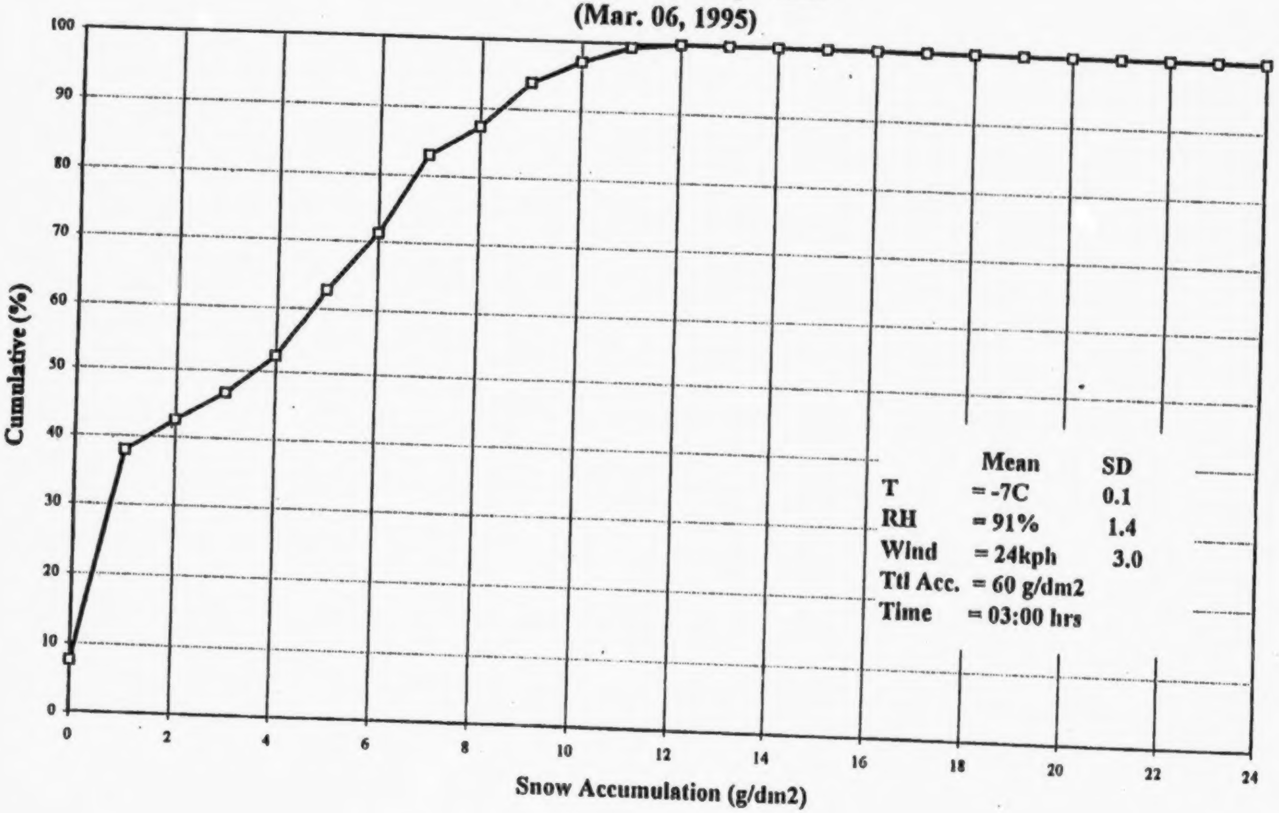
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Feb. 27, 1995)**



18/8/95 16:14

950227.XLS

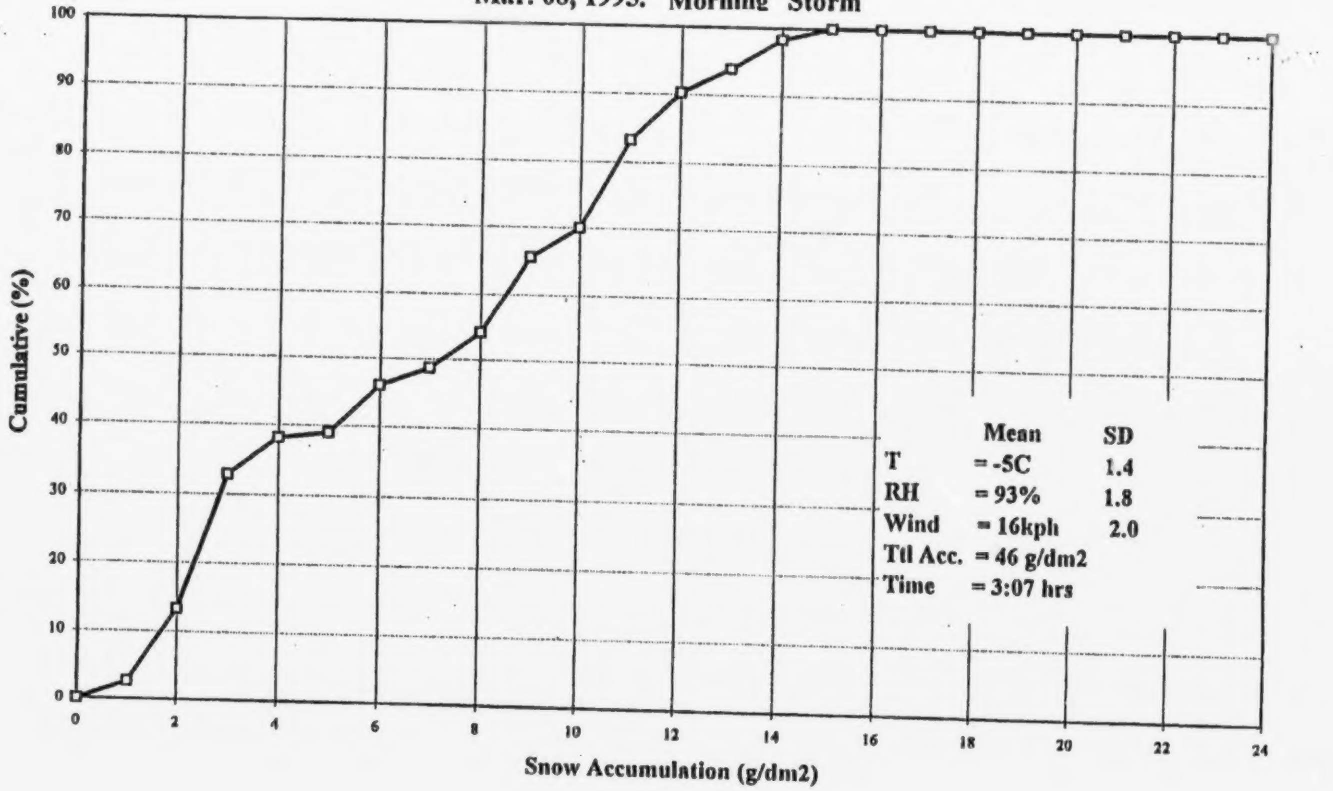
**Distribution of Snow Accumulation**
**For 21 min. at Every 3 min.**
**(Mar. 06, 1995)**



18/8/95 16:03

950306.XLS

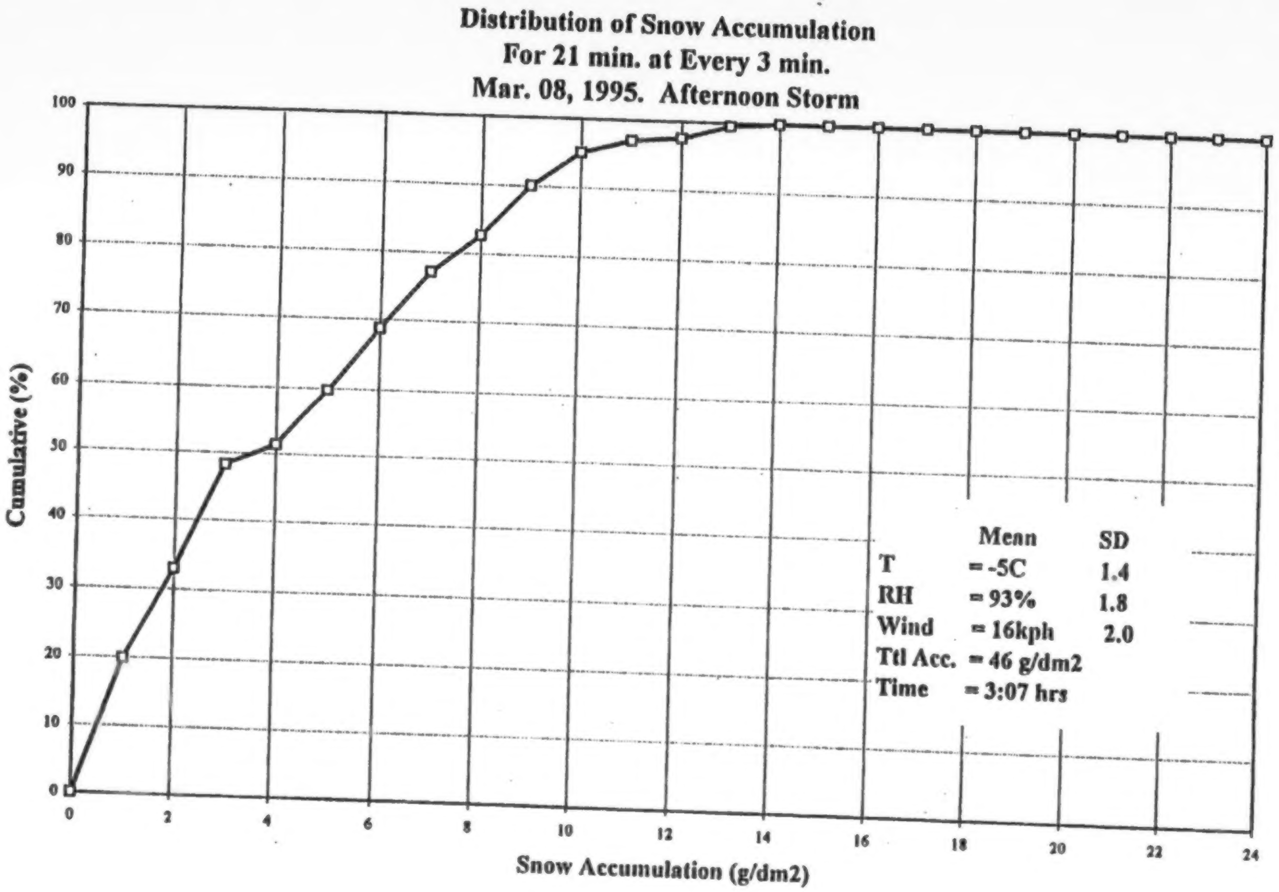
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Morning Storm



| | Mean | SD |
|---|---|---|
| T | = -5C | 1.4 |
| RH | = 93% | 1.8 |
| Wind | = 16kph | 2.0 |
| Ttl Acc. | = 46 g/dm2 | |
| Time | = 3:07 hrs | |

17/8/95 13:43

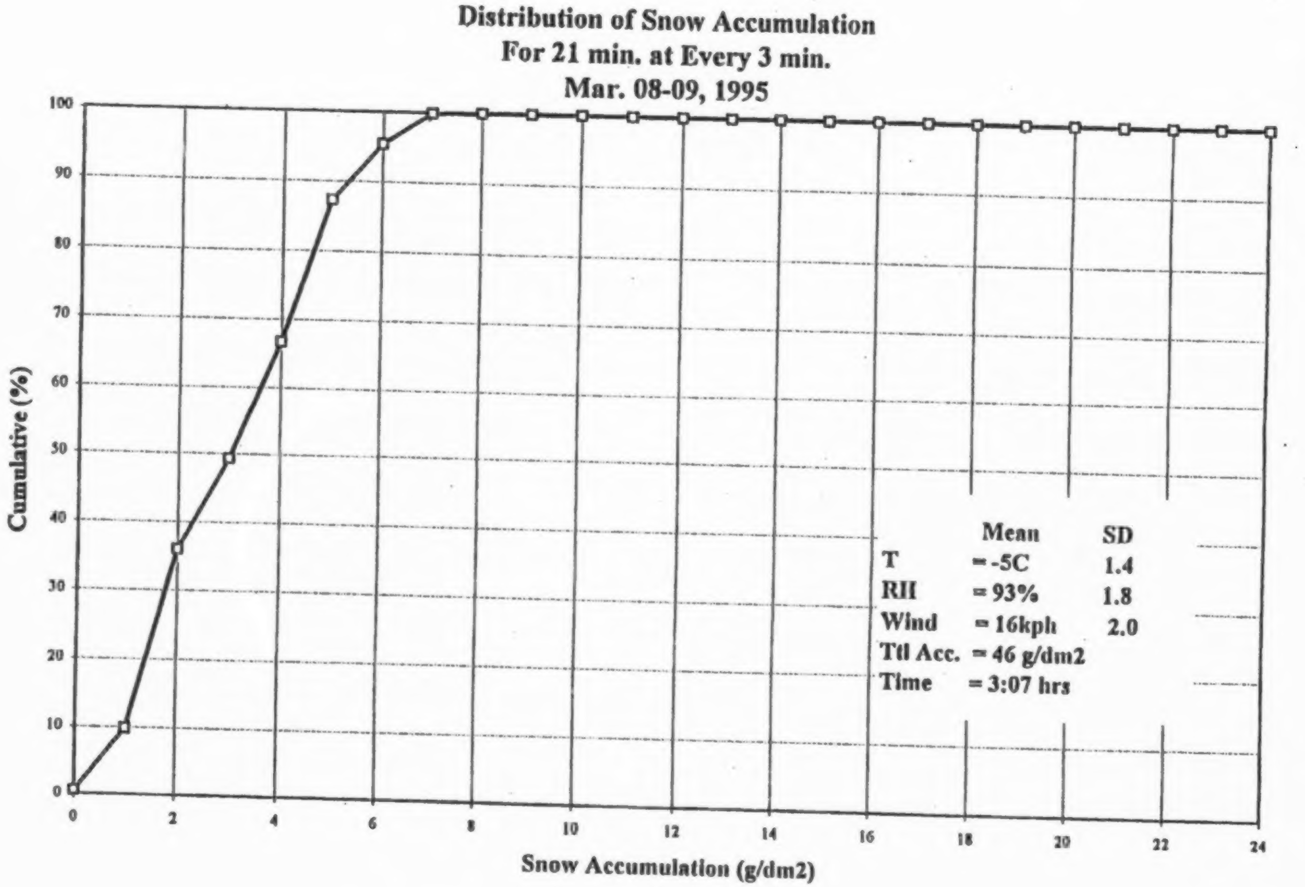
950308.XLS



Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Afternoon Storm

18/8/95 15:58

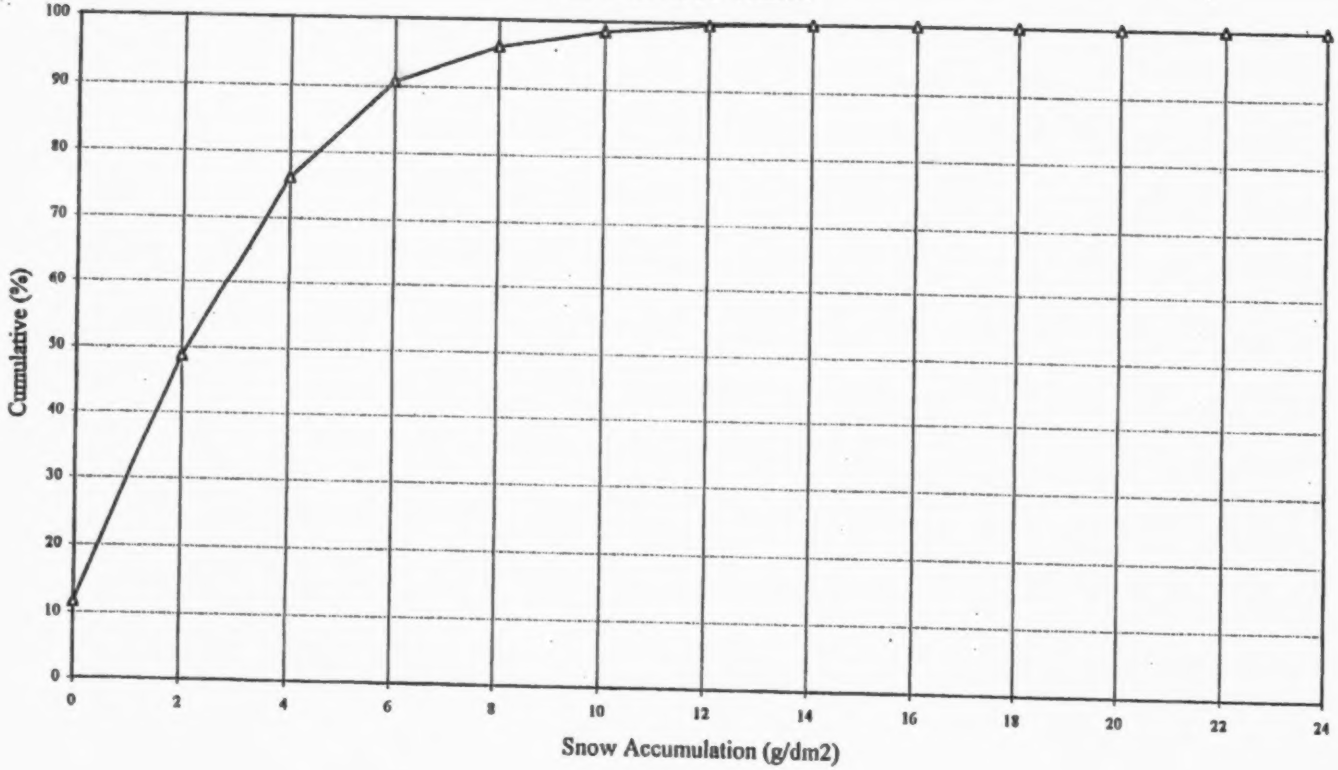
950308.XLS



17/8/95 13:43

950308.XL

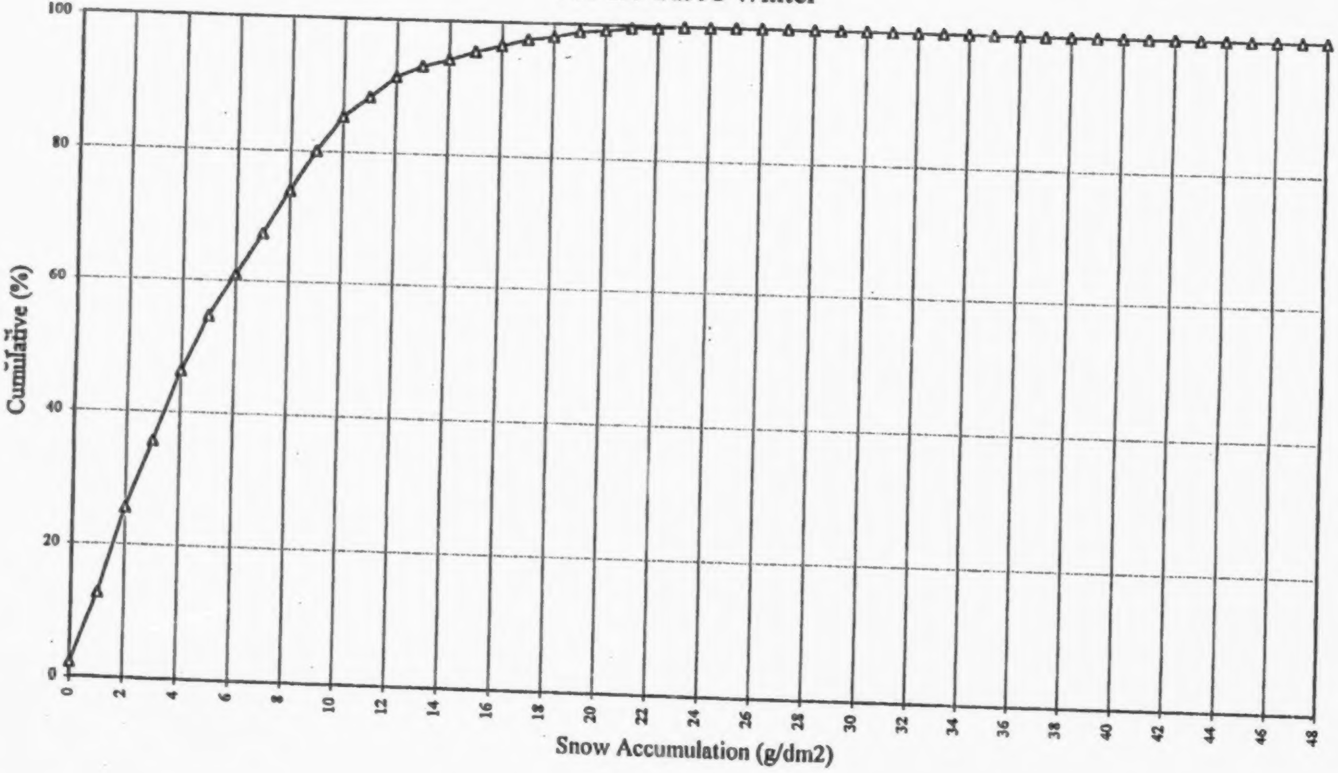
## Distribution for Snow Accumulation
## For 21 min. at Every 3 min.
## For 1994/1995 Winter



18/8/95 15:25

MHIST95.XL

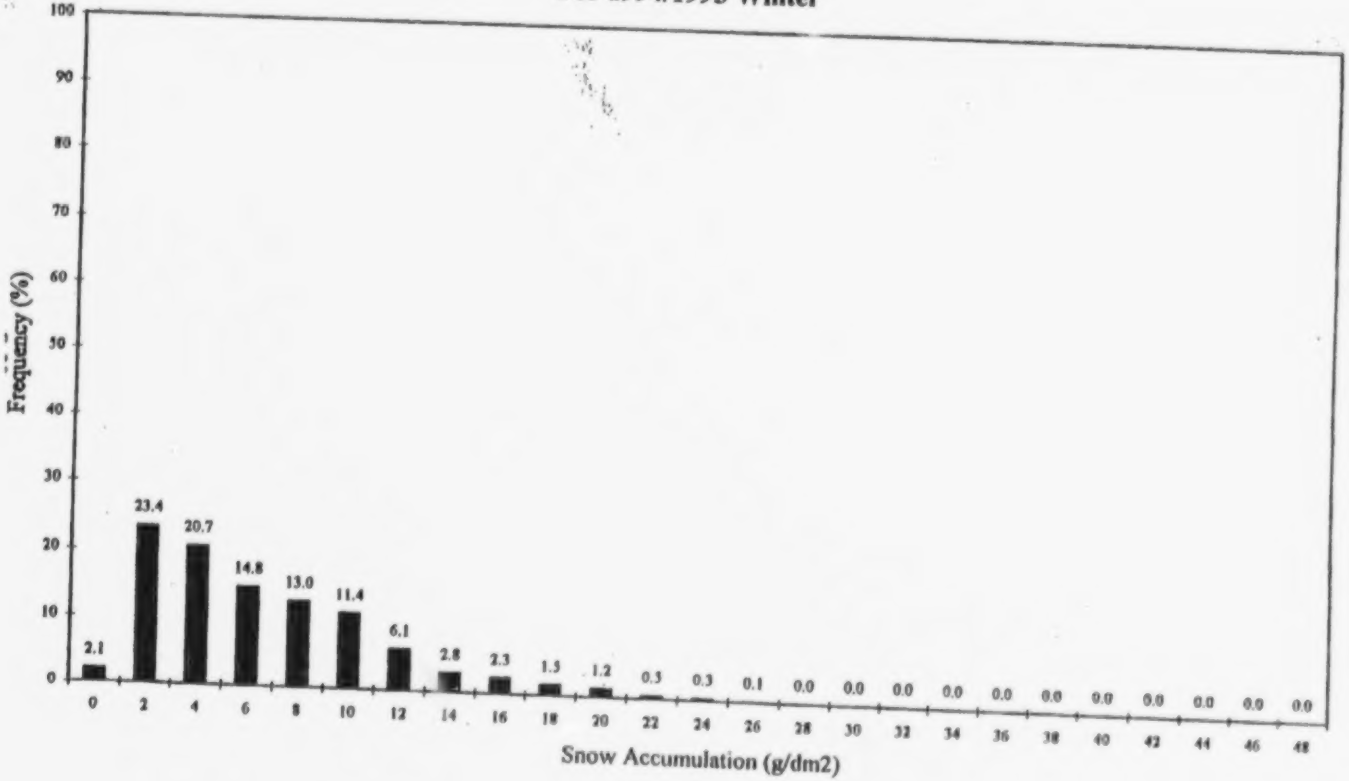
**Distribution for Snow Accumulation**
**For 45 min. at Every 3 min.**
**For 1994/1995 Winter**



18/8/95 14:32

MHIST95.XLS

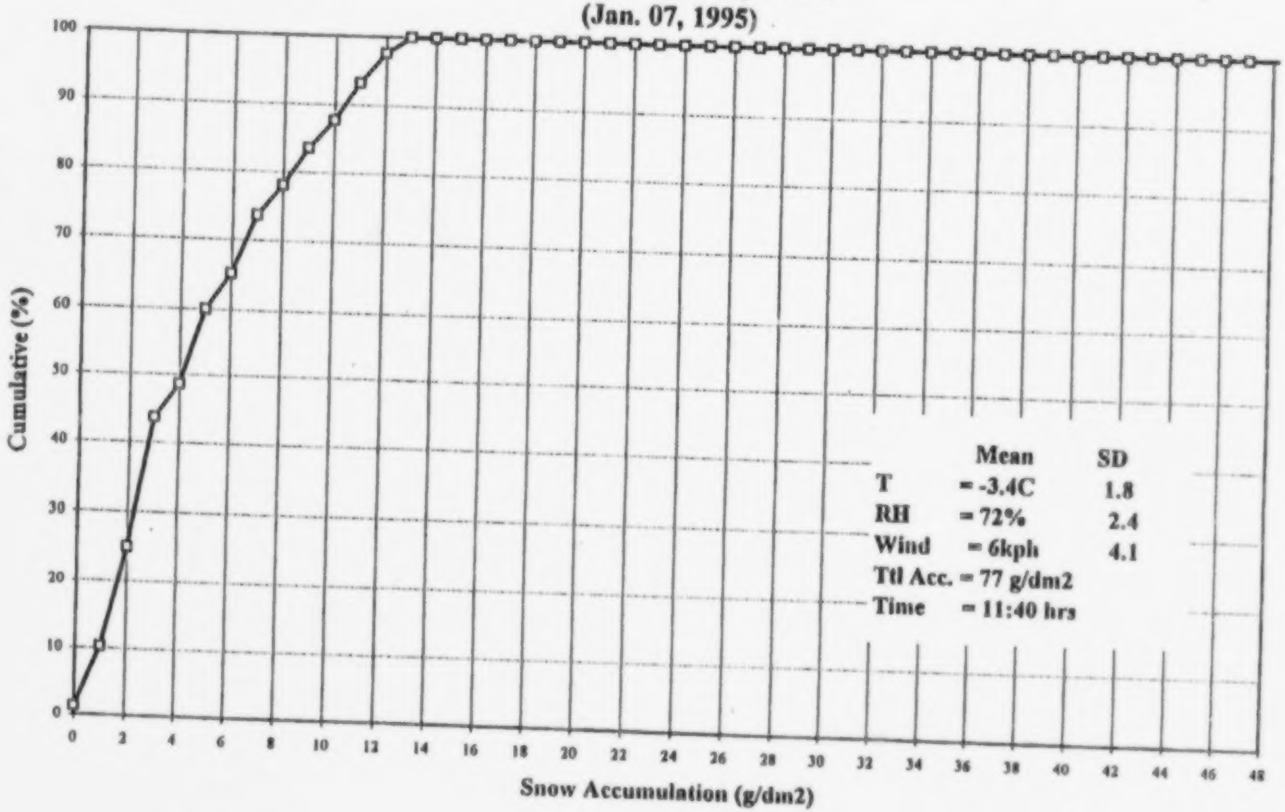
## Histogram for Snow Accumulation
## For 45 min. at Every 3 min.
## For 1994/1995 Winter



18/8/95 14:28

MHIST95.XLS

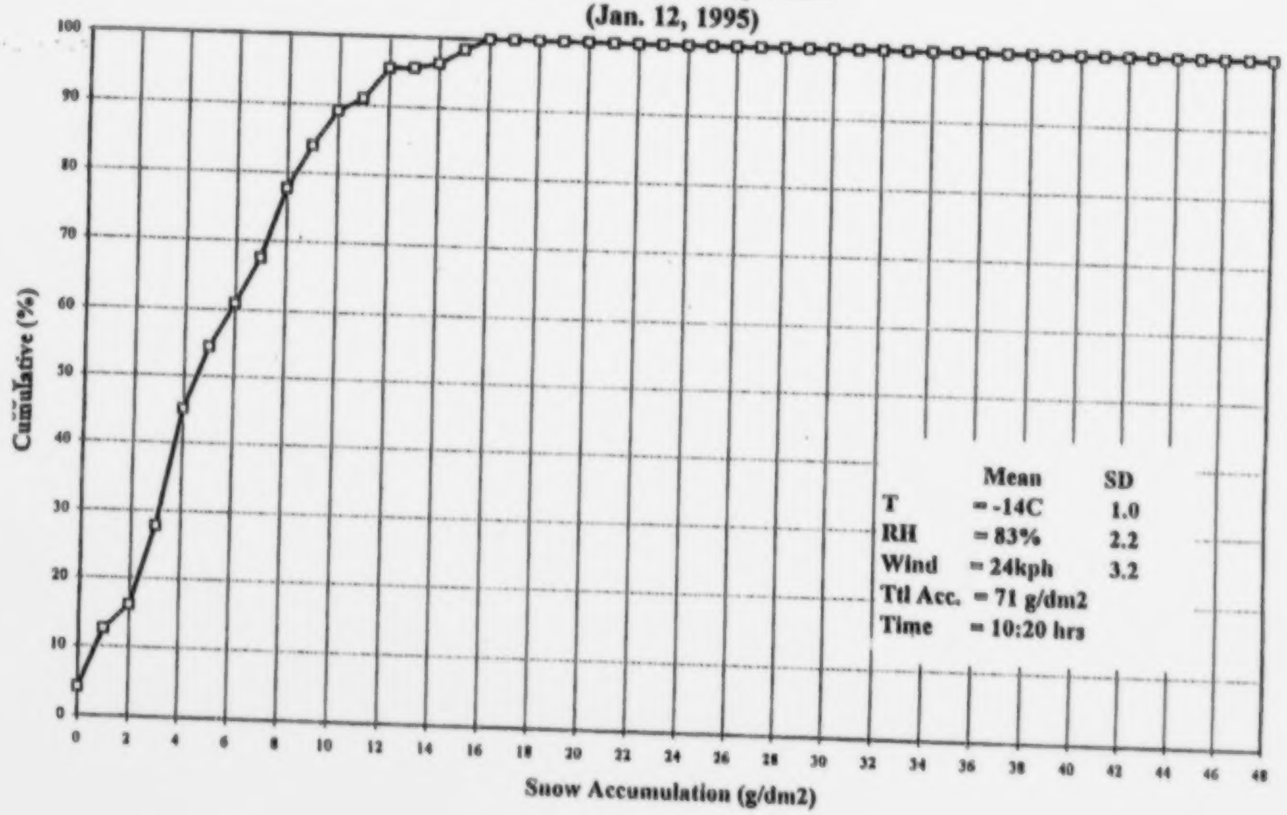
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 07, 1995)



18/8/95 15:36

950107.XLS

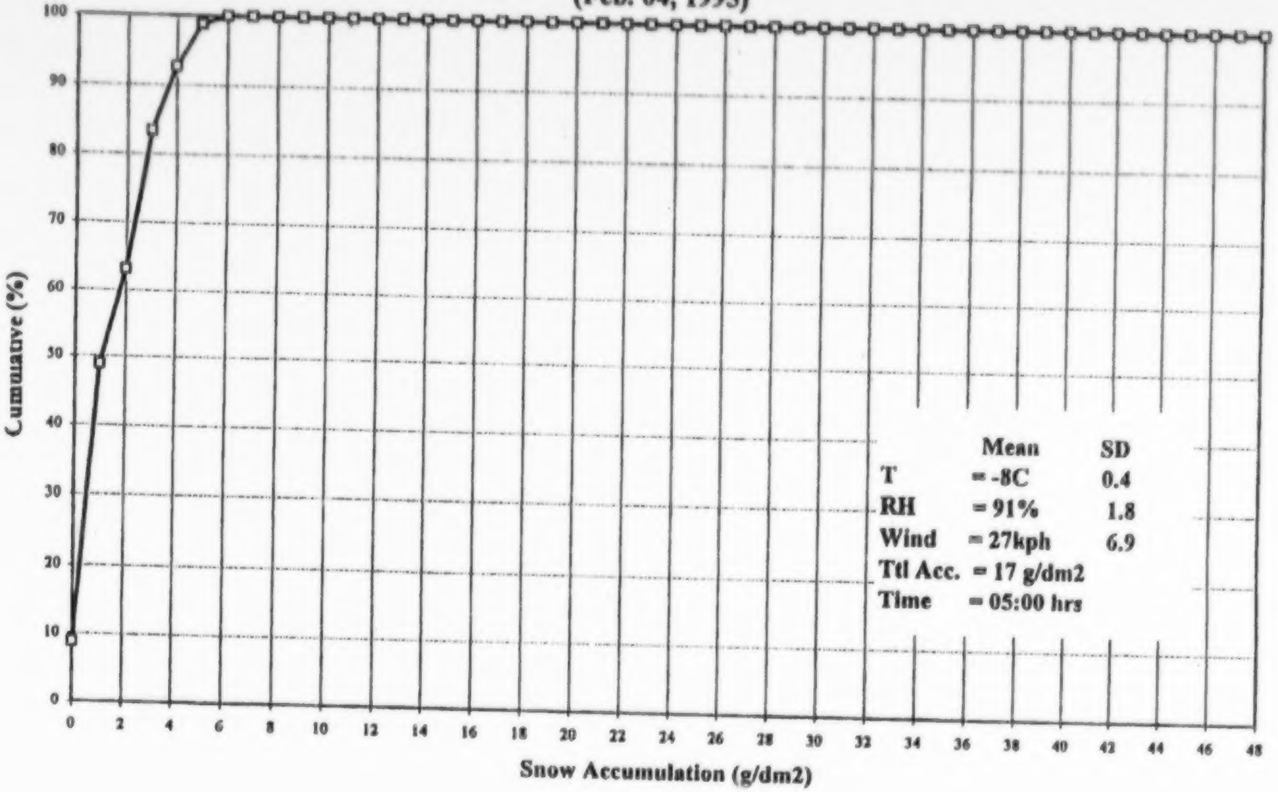
## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Jan. 12, 1995)



18/8/95 15:34

950112.XLS

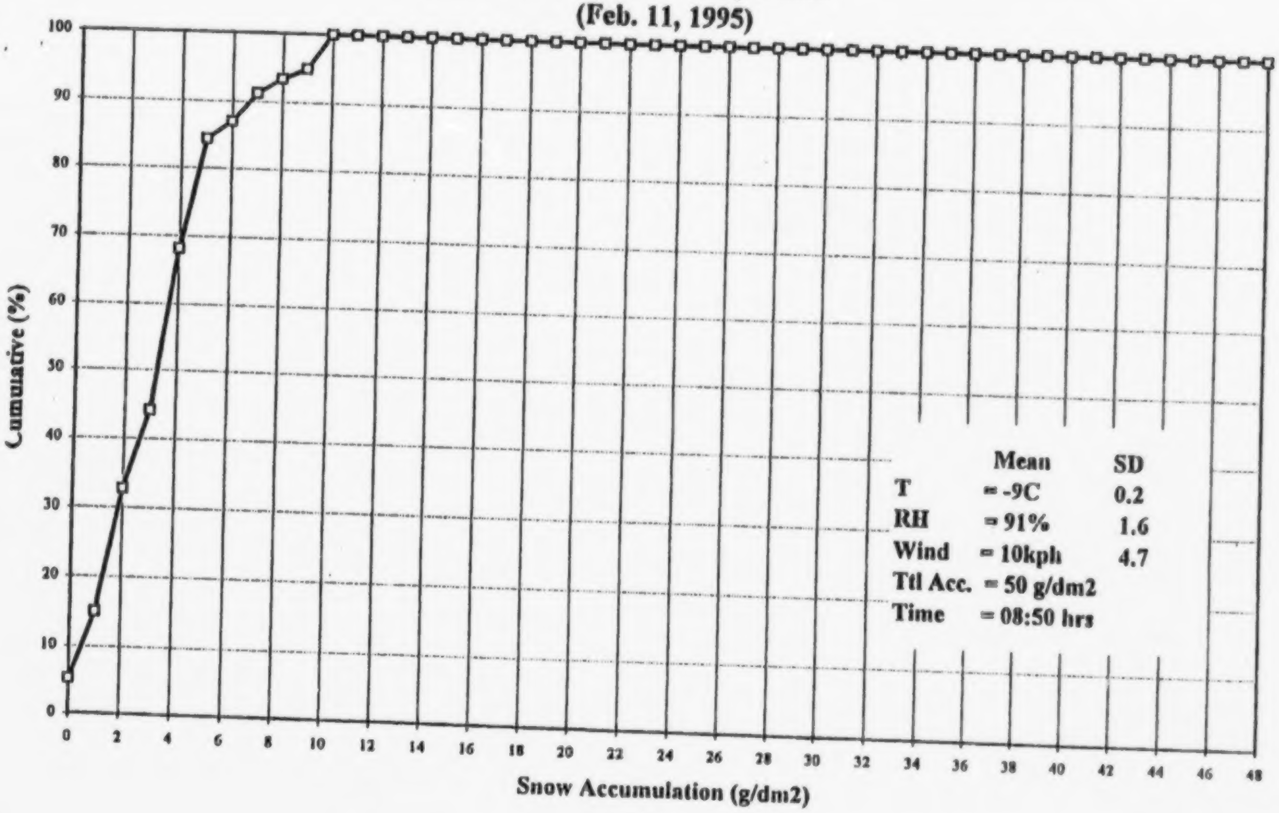
## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Feb. 04, 1995)



18/8/95 15:51

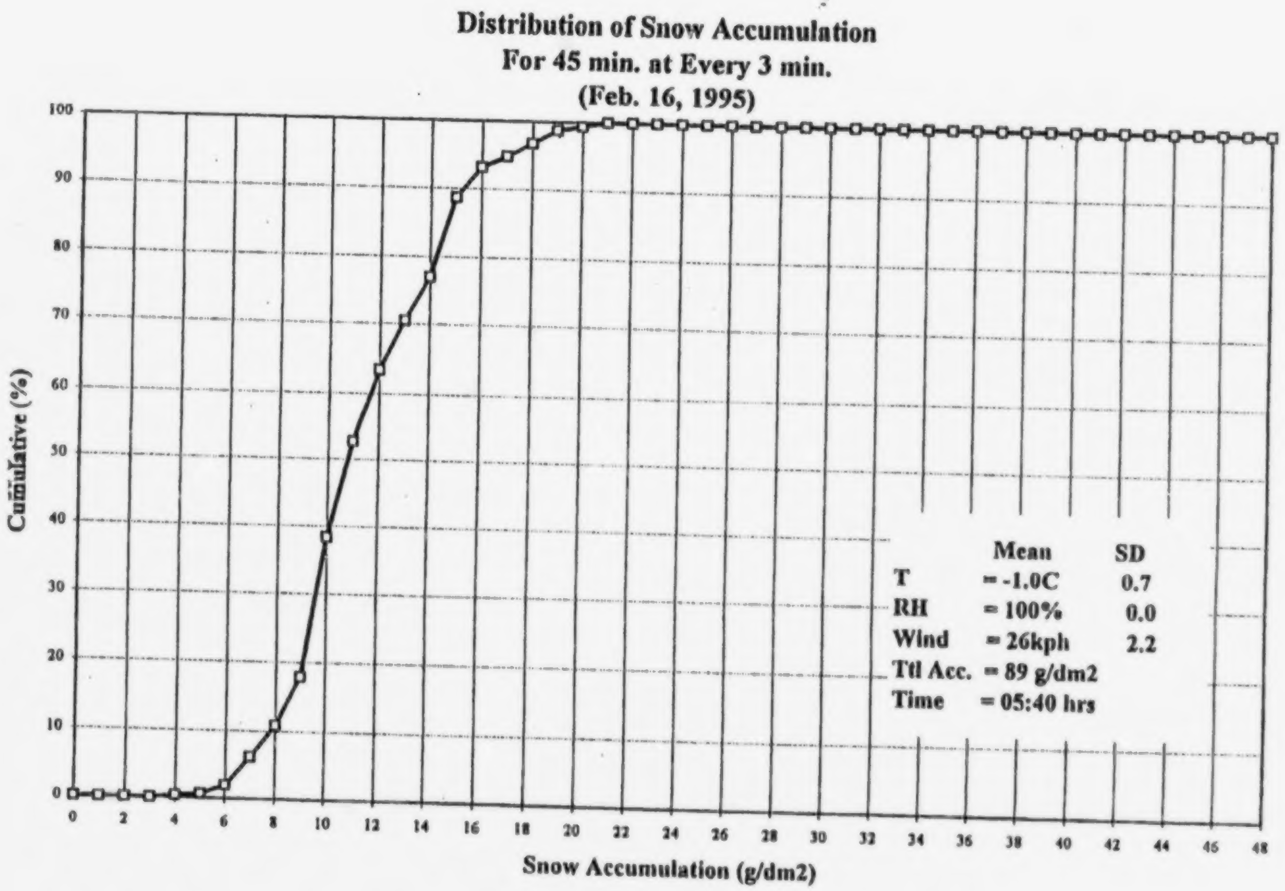
950204.XLS

## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Feb. 11, 1995)



18/8/95 15:49

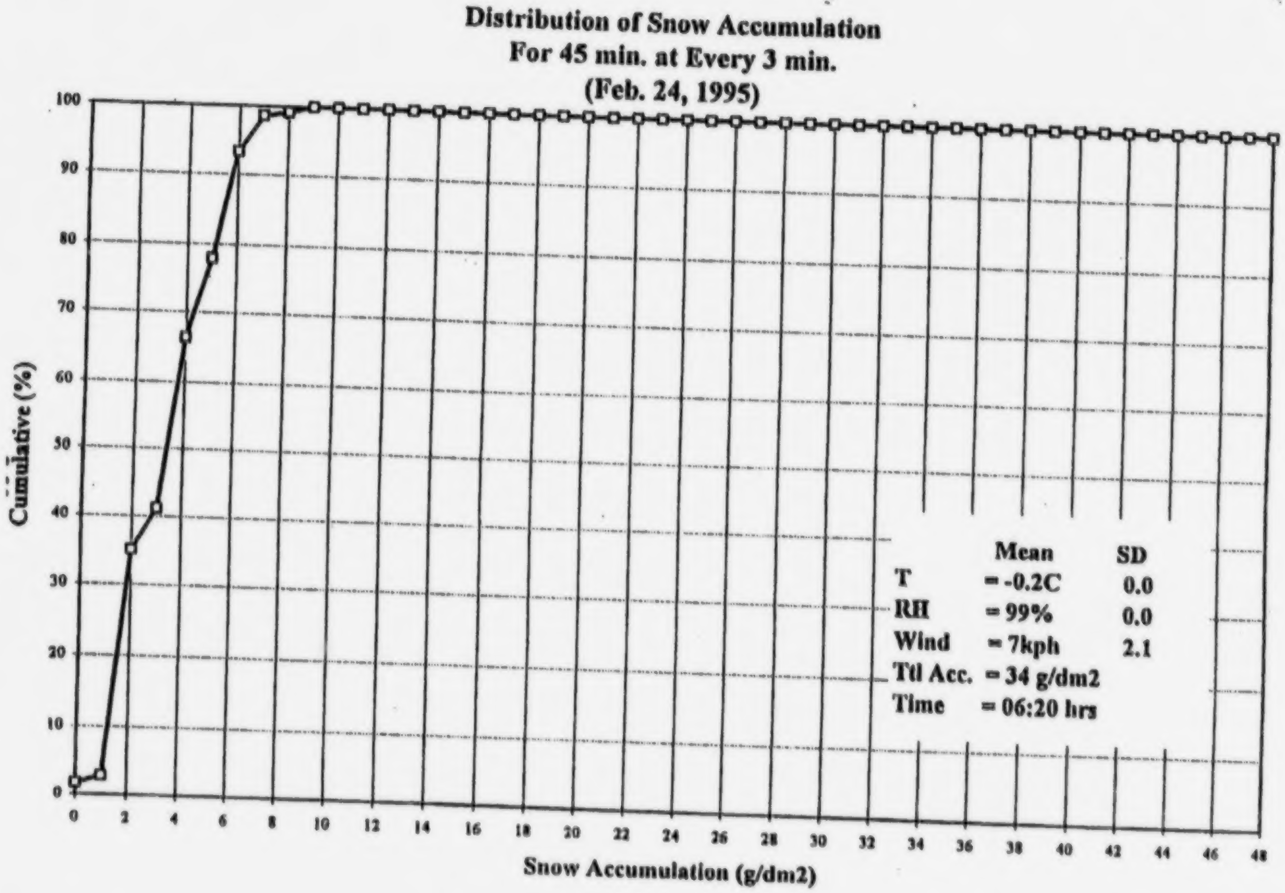
950211.XLS



Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 16, 1995)

18/8/95 15:48

950216.XLS



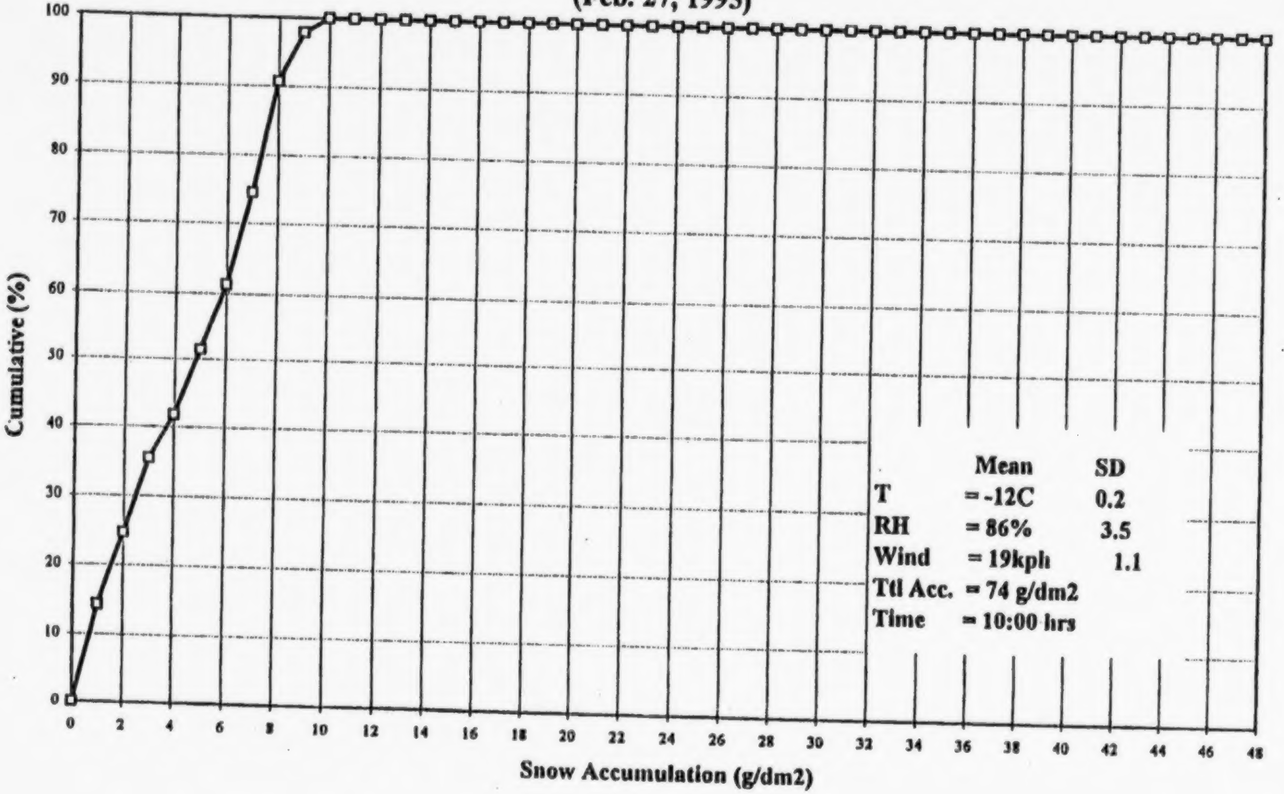
**Distribution of Snow Accumulation**
**For 45 min. at Every 3 min.**
**(Feb. 24, 1995)**

| | Mean | SD |
|---|---|---|
| T | = -0.2C | 0.0 |
| RH | = 99% | 0.0 |
| Wind | = 7kph | 2.1 |
| Ttl Acc. | = 34 g/dm2 | |
| Time | = 06:20 hrs | |

18/8/95 15:44

950224.XLS

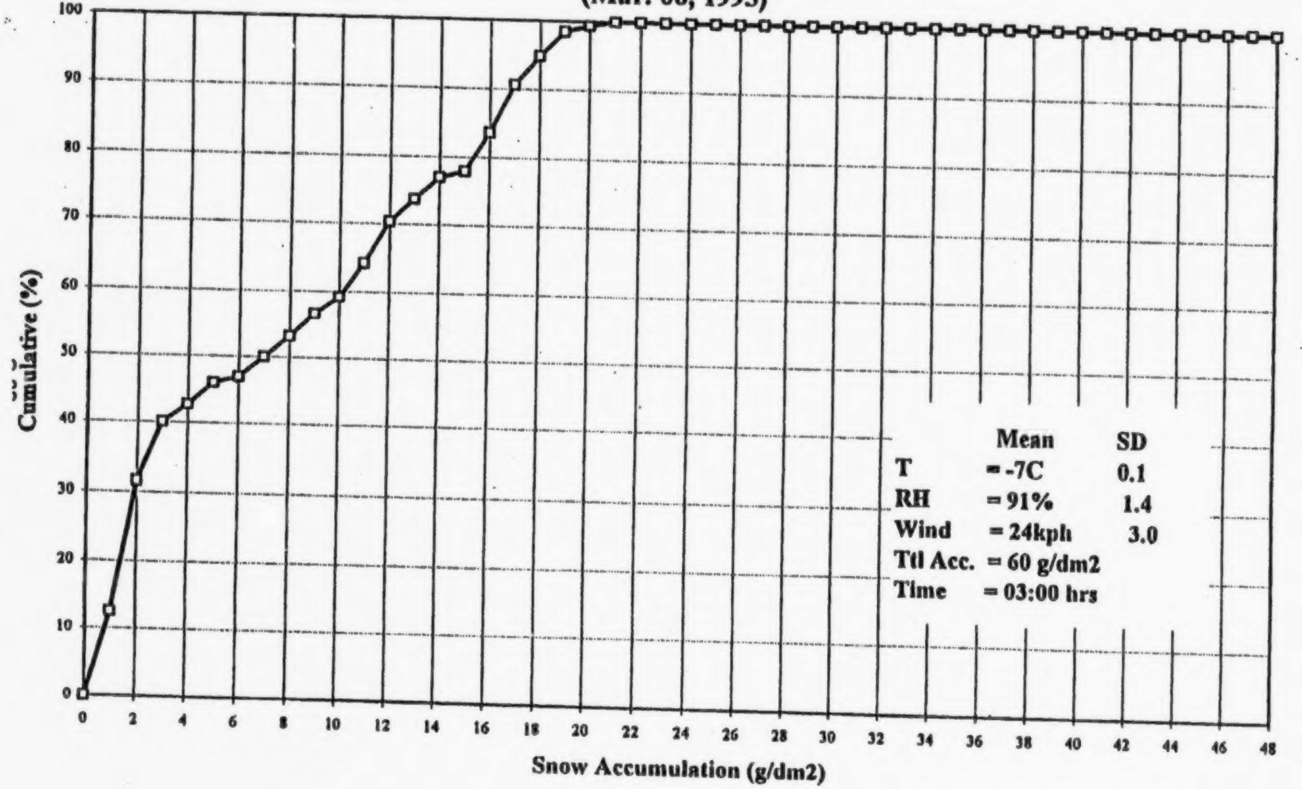
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 27, 1995)



18/8/95 15:41

950227.XLS

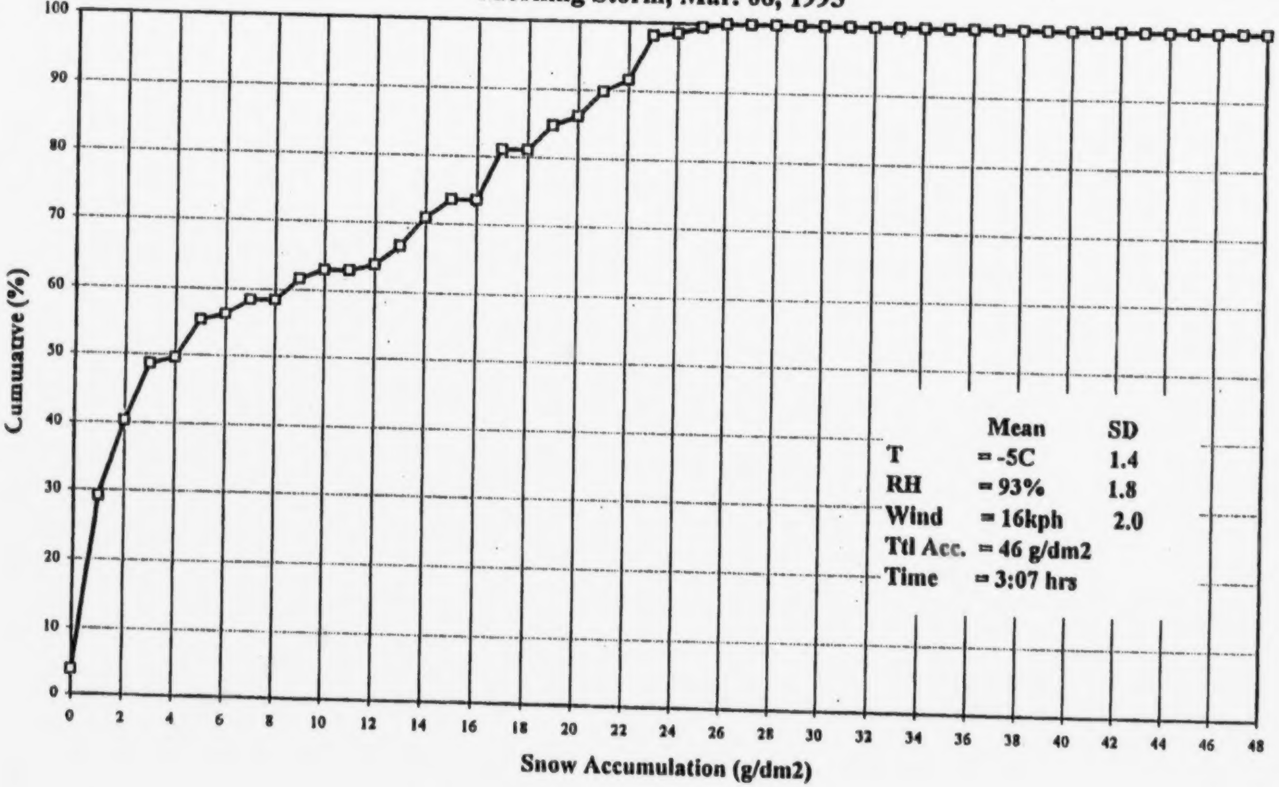
## Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 06, 1995)



18/8/95 16:03

950306.XLS

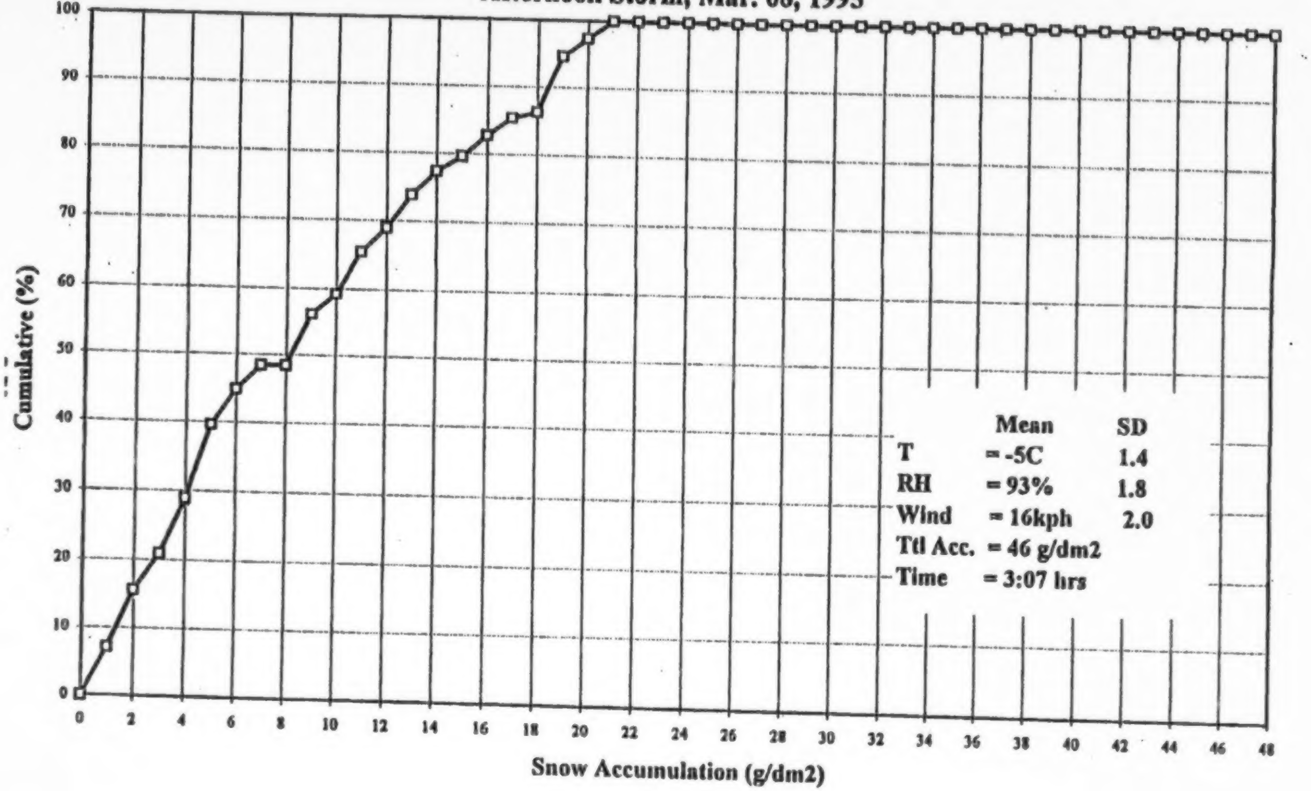
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Morning Storm, Mar. 08, 1995



18/8/95 15:55

950308.XLS

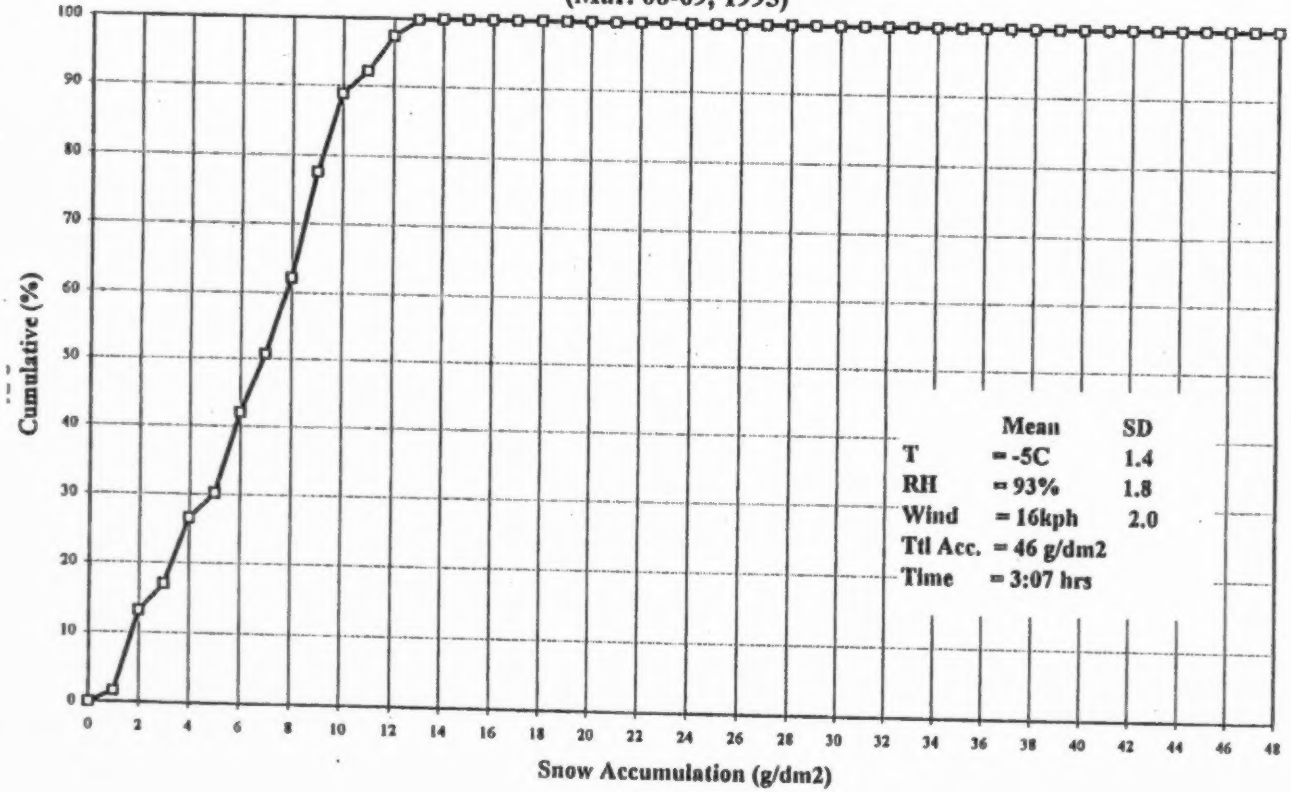
**Distribution of Snow Accumulation**
**For 45 min. at Every 3 min.**
**Afternoon Storm, Mar. 08, 1995**



18/8/95 15:55

950308.XLS

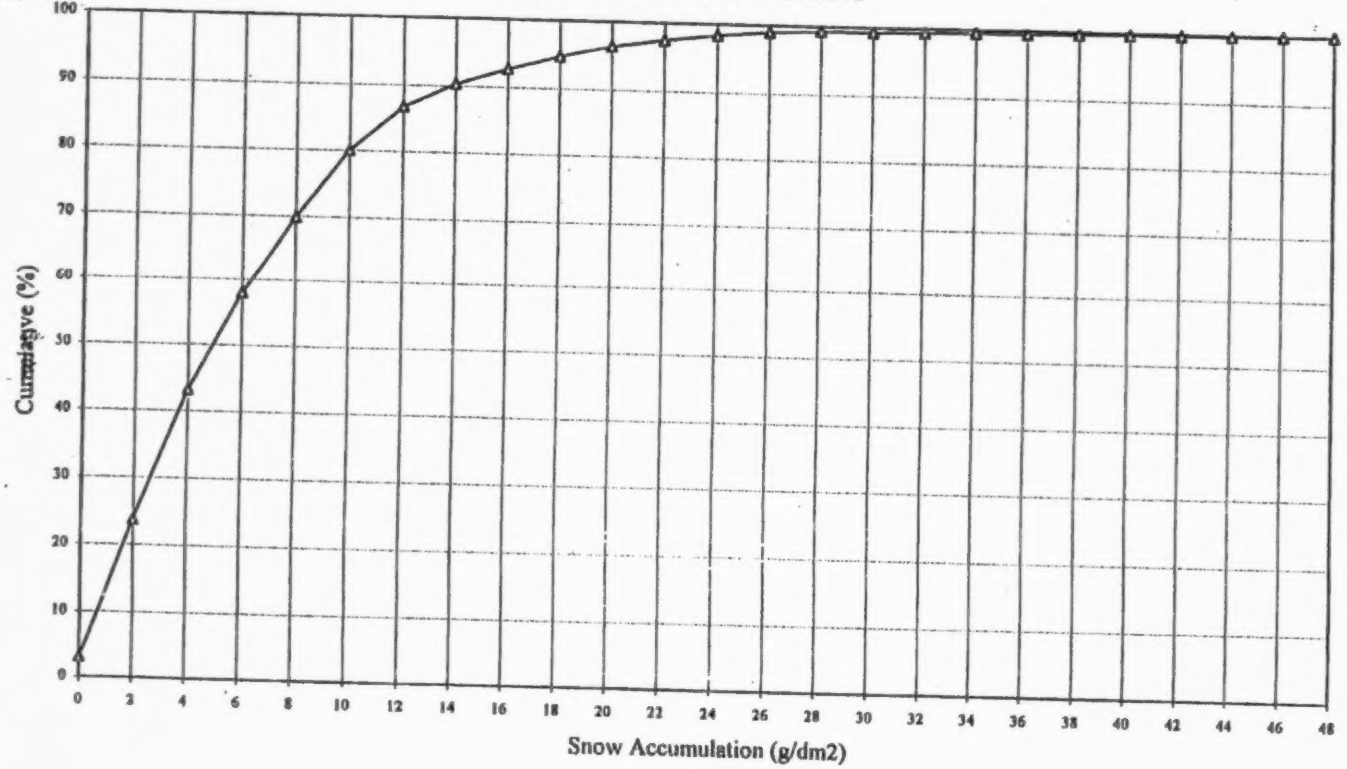
## Distribution of Snow Accumulation
## For 45 min. at Every 3 min.
## (Mar. 08-09, 1995)



18/8/95 15:55

950308.XLS

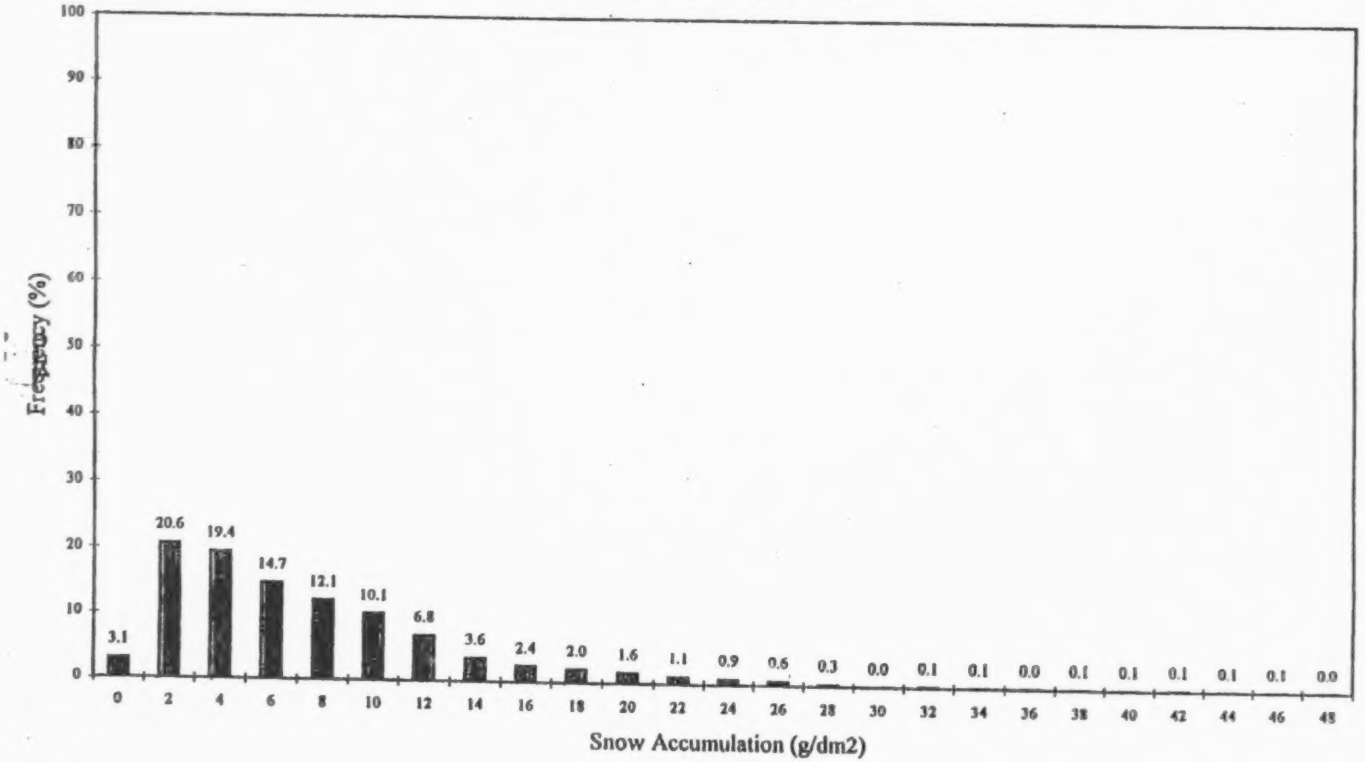
## Distribution for Snow Accumulation
## For 45 min. at Every 3 min.
## For 1993/94-1994/95 Winters



18/8/95 12:09

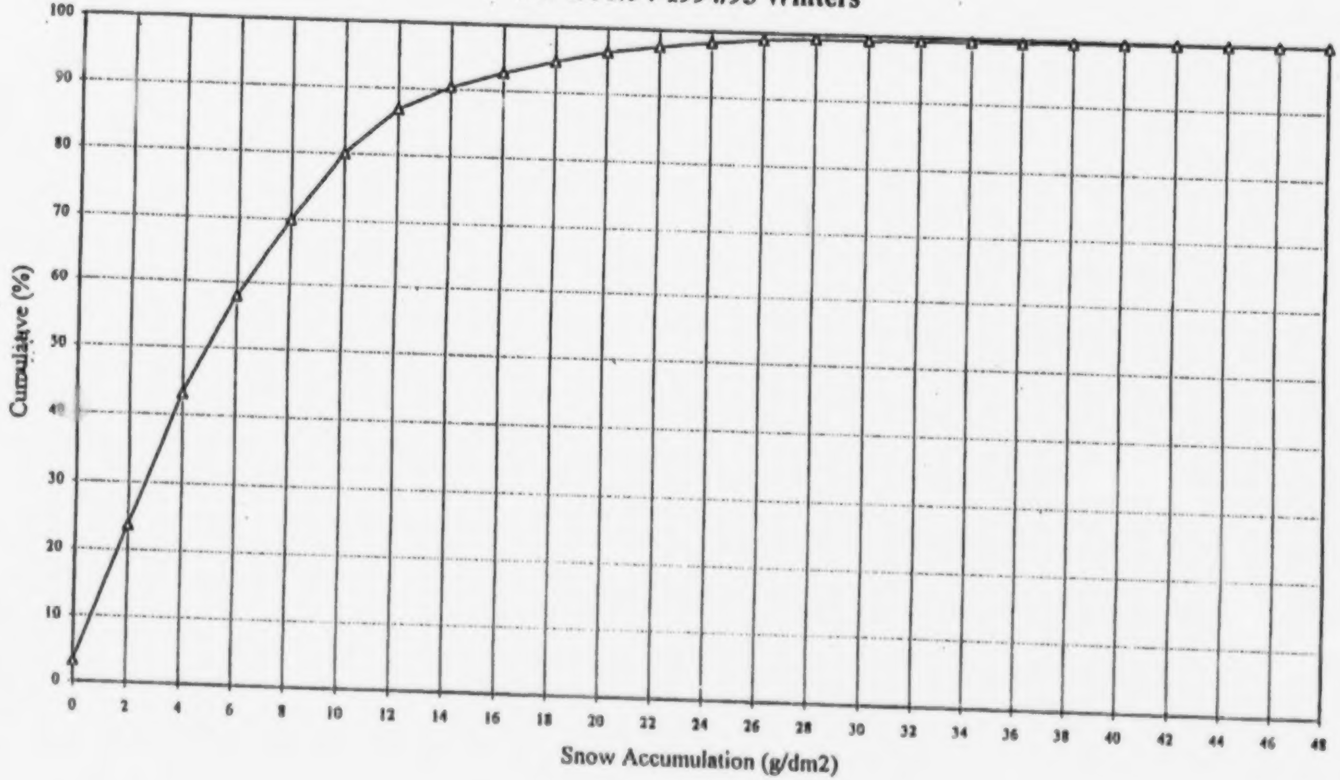
MHIST95.XLS

## Histogram for Snow Accumulation
## For 45 min. at Every 3 min.
## For 1993/94-1994/95 Winters



18/8/95 12:10

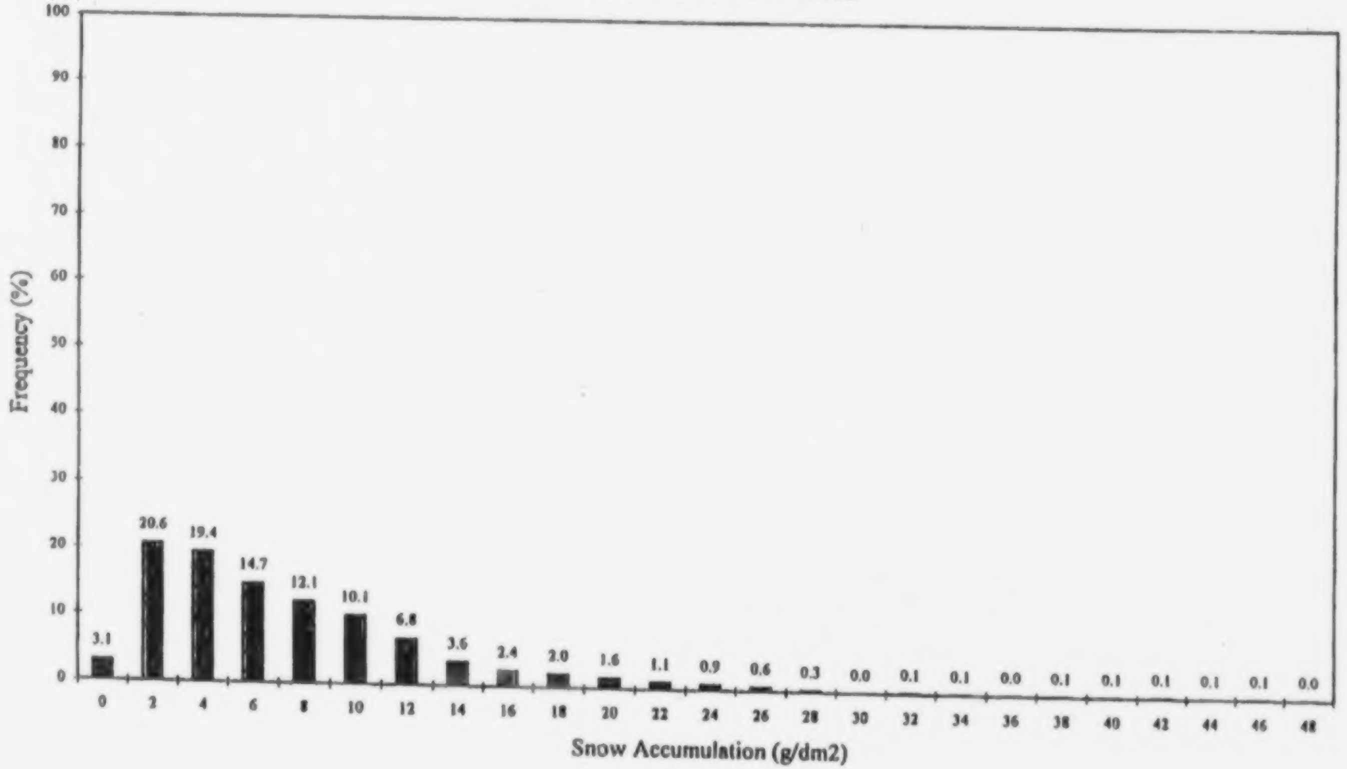
MHIST95.XLS



Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters

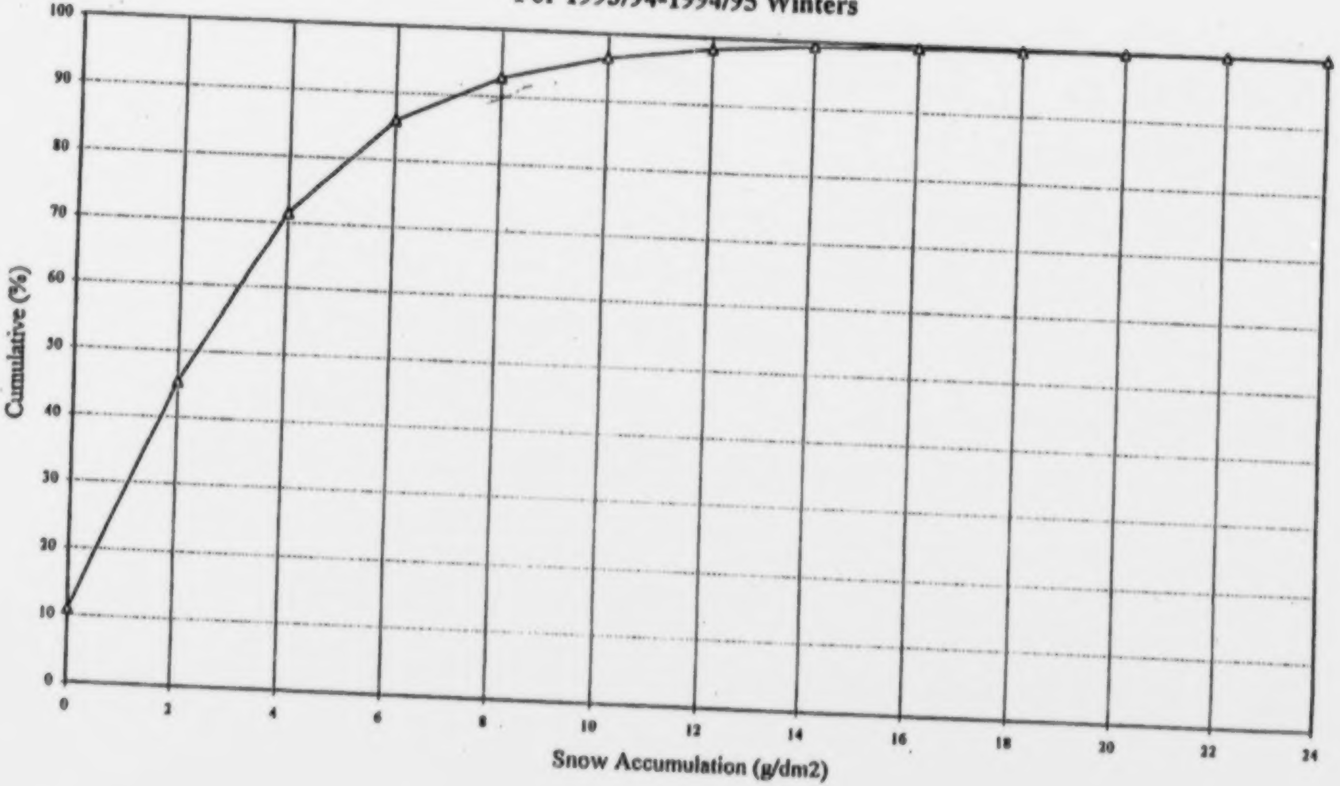
18/8/95 12:09

**Histogram for Snow Accumulation**
**For 45 min. at Every 3 min.**
**For 1993/94-1994/95 Winters**



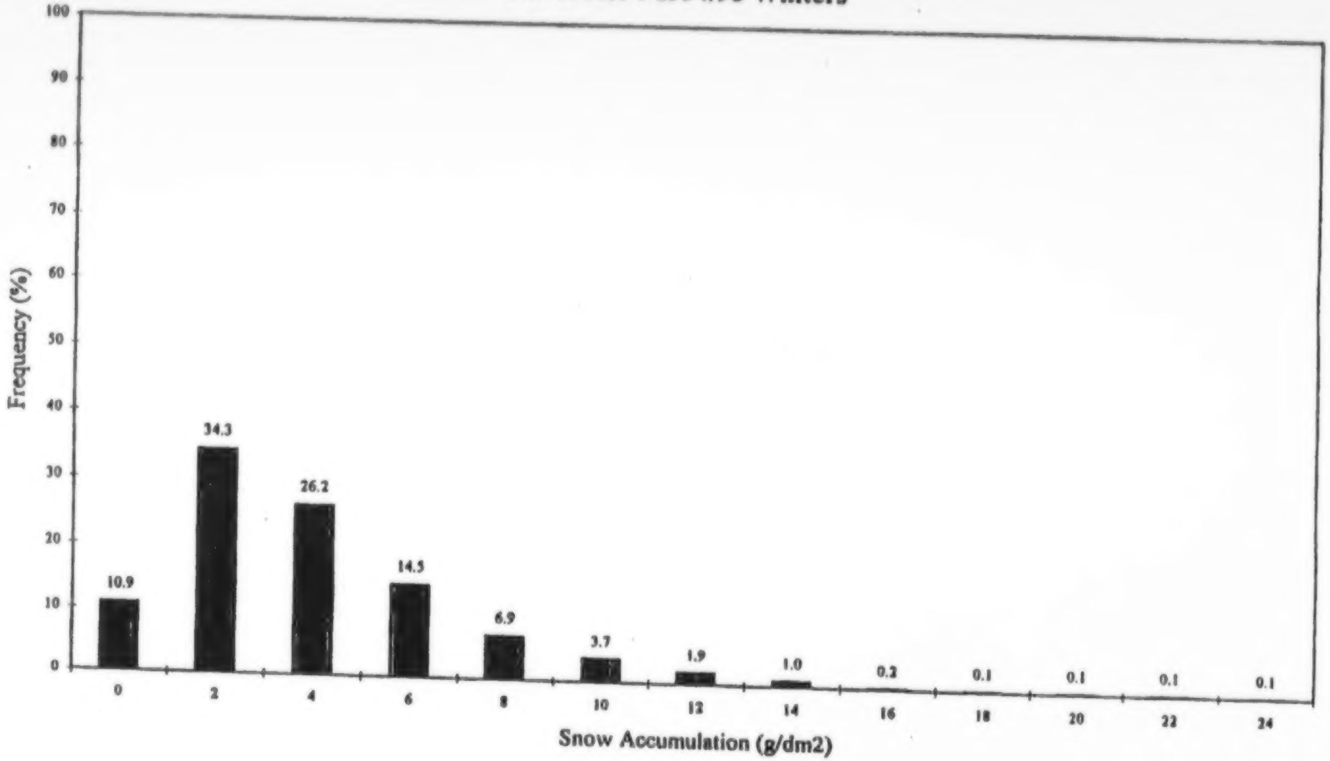
18/8/95 12:10

**Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters**



17/8/93 13:55

## Histogram for Snow Accumulation
## For 21 min. at Every 3 min.
## For 1993/94-1994/95 Winters



17/8/95 12:10

# APPENDIX D

## METEOROLOGICAL SERVICE OF CANADA STUDY

## FREQUENCY OF OCCURRENCE OF WATER EQUIVALENT PRECIPITATION RATES AS A FUNCTION OF AVERAGING TIME, TEMPERATURE AND TYPE

# Draft

## Frequency of Occurrence of Water Equivalent Precipitation Rates as a function of Averaging Time, Temperature and Type

### 1.0 Introduction

The proposed Holdover Time Tables give the failure time of various types of anti-icing fluids for different precipitation types, temperatures and water equivalent precipitation rates. In order to specify realistic precipitation rates in these tables, the cumulative probability distribution of rates averaged over the different holdover times must be determined. This report presents these distributions using data collected from an experimental site situated at Pearson International Airport established in 1995 with Dryden Commission Implementation Project funding to study nowcasting of on-ground aircraft icing.

### 2.0 Precipitation rate measurement

There is no internationally recognized "reference" instrumentation for measuring precipitation rate. Standard automated weighing gauges do not have sufficient resolution to report rate with the minutely time resolution required. Meteorological observers report an "intensity" of precipitation in four categories: very light, light, moderate and heavy. This is based on a broad classification of rate which is inadequate for the nowcasting of the holdover times. The observer also makes climatological measurements of accumulated amounts of precipitation every six hours. In the case of frozen precipitation the amount reported is the "water equivalent" of the melted precipitation.

One of the objectives of the experiment at Pearson International Airport (YYZ) was to evaluate the performance of new technologies designed to measure precipitation rates in both liquid and frozen phases with minutely reporting resolution. Several sensors were evaluated and it was determined that a small Doppler radar called the Precipitation Occurrence Sensor System (POSS) agreed the best with the observed 6-hourly accumulated precipitation amounts. This study will be reported on elsewhere.

## 2.1 POSS

The Precipitation Occurrence Sensor System is a small Doppler X-band radar designed by the Atmospheric Environment Service as a present weather sensor for its automatic weather observing stations. It is commercially manufactured under licence by Andrew Antenna, Canada. The sensor reports every minute the occurrence, type, intensity, rate and accumulation of precipitation.

The precipitation rate is estimated using the same method as is done with large-scale precipitation radars. The method, referred to as the "Z-R" method, measures the radar reflectivity factor (Z) to estimate the precipitation rate (R).

## 3.0 Analysis

The water equivalent precipitation rate is reported by the POSS every minute. These rates are averaged using a "sliding box car " for the three specified periods used in the holdover time tables: 6, 20 and 35 minutes. The data is then classified into three precipitation types as reported by the meteorological observer at the site: snow, freezing rain of light intensity and freezing drizzle. In the case of mixed precipitation types the data is included in a class if that type is reported as one of the mixed types. The data is further classified into the four temperature ranges proposed in the Holdover time tables: 0 to -3C, -3 to -7C, -7 to -14C and -14 to -25C.

The frequency of occurrence with respect to the average water equivalent precipitation rate is determined. The average is included in these statistics only if at least half the minutes have non-zero precipitation rates. In addition, if there is missing data, then at least have the averaging time must have valid measurements. This approach deliberately excludes intermittent precipitation from biasing the percentile statistics.

## 4.0 Results

The results are presented graphically in plots of cumulative probability versus precipitation rate averaged over a specified period. The cumulative probability at a specific precipitation rate is the percentage of the dataset with precipitation rates less than that rate. There is one graph for each combination of averaging time and temperature (see Figures below).

Each graph displays a curve for each of the three precipitation classes.

In snow, the 95% percentile of the water equivalent precipitation rate averaged over 6 minutes decreases with temperature from about 1.6 mm/h at 0 to -3C to 0.8 mm/h at -14 to -25C. Similar results were found for the other averaging times.

The 95% percentile for light freezing rain is 4.3 mm/h for a 6-minute averaging time in the temperature range 0 to -3C. Light freezing rain did not occur below -3C.

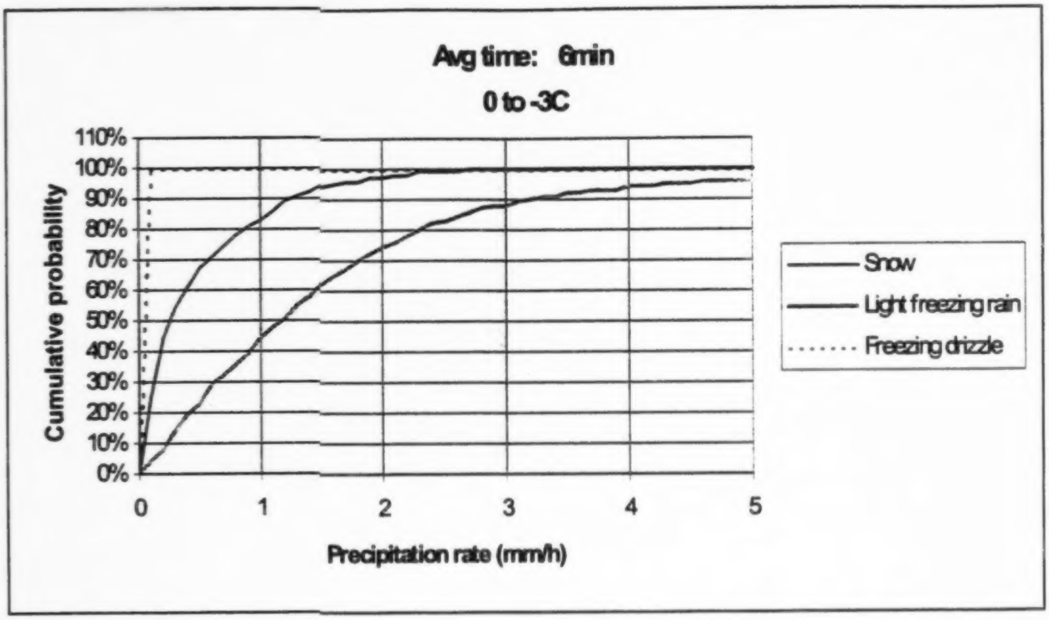
There were few occurrences of freezing drizzle from this location during the experimental period.

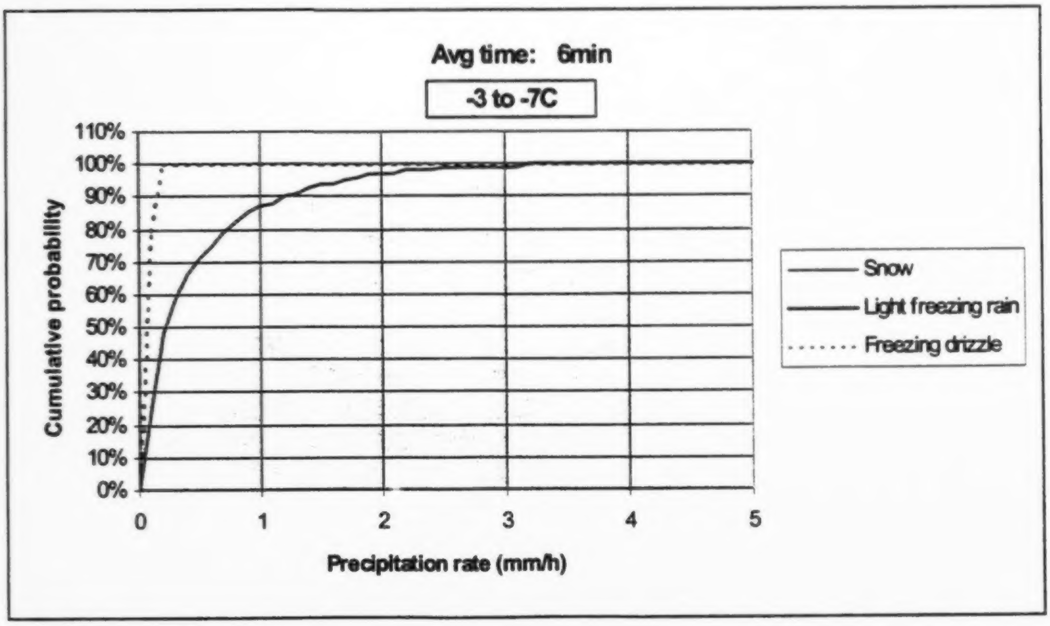
A second set of graphs compares the effect of changing the averaging time for calculating the precipitation rate for snow and freezing rain of light intensity. The cumulative probability curves in snow for the temperature range 0 to -3C are very similar, with the 95% percentile constant at 1.6 mm/h.

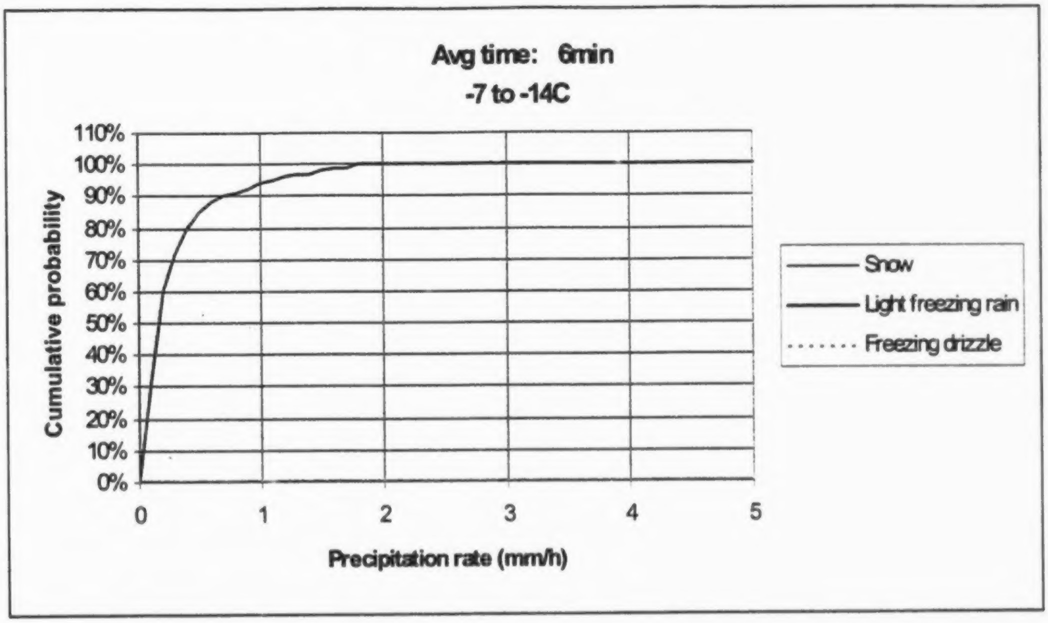
In light freezing rain the 95% percentile is also quite constant although other percentiles are more strongly affected.

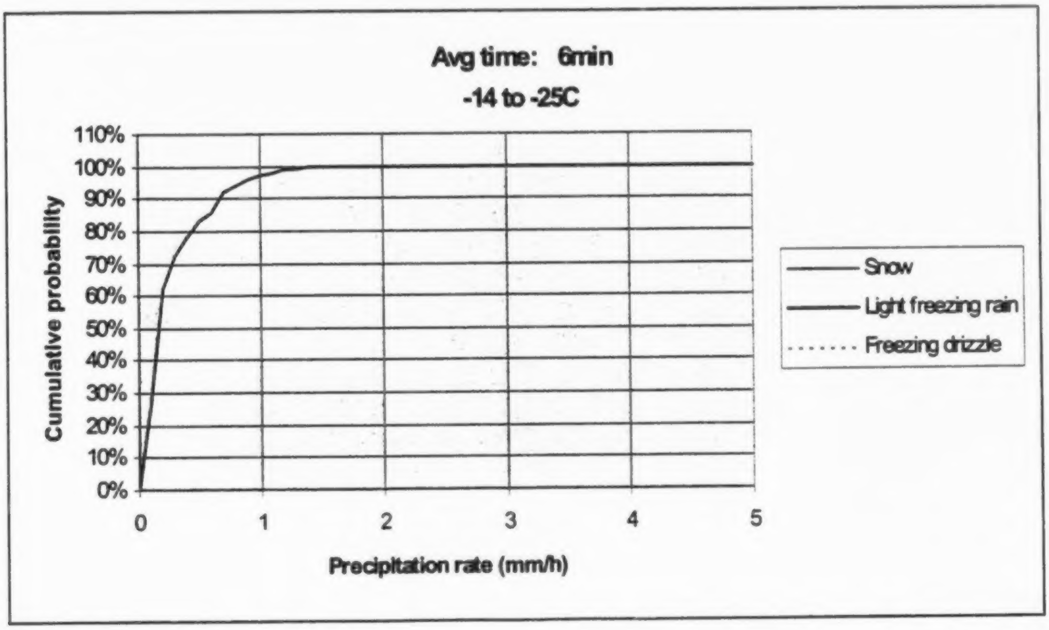
The averaging time will have the greatest influence when the precipitation rate is variable. This preliminary analysis indicates that the rates in snow are less variable than in light freezing rain.

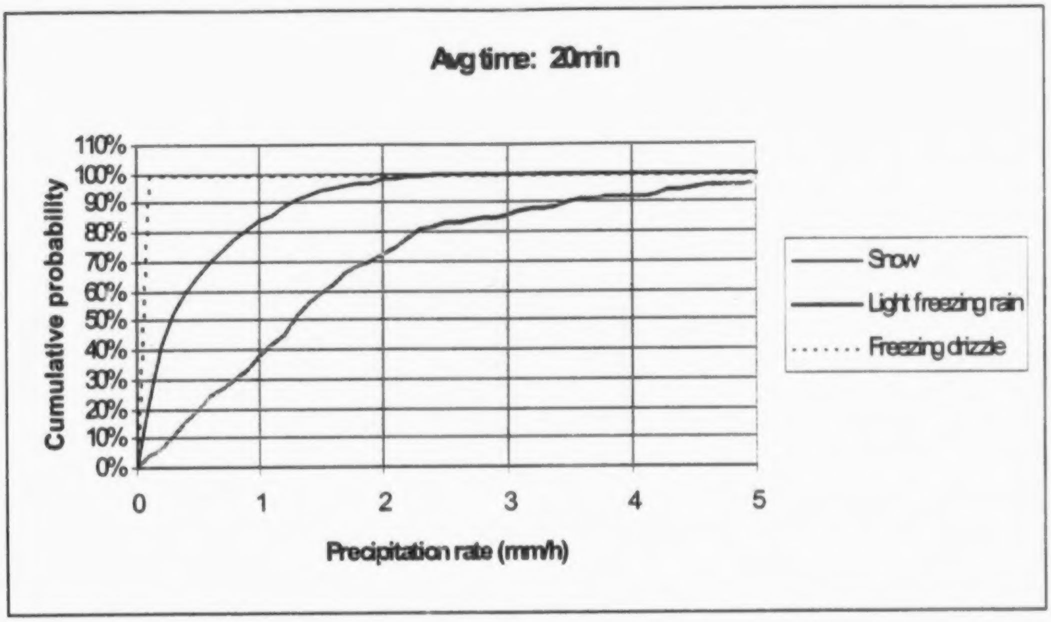
B.E. Sheppard
BRIAN.SHEPPARD@EC.GC.CA
17 Nov. 97

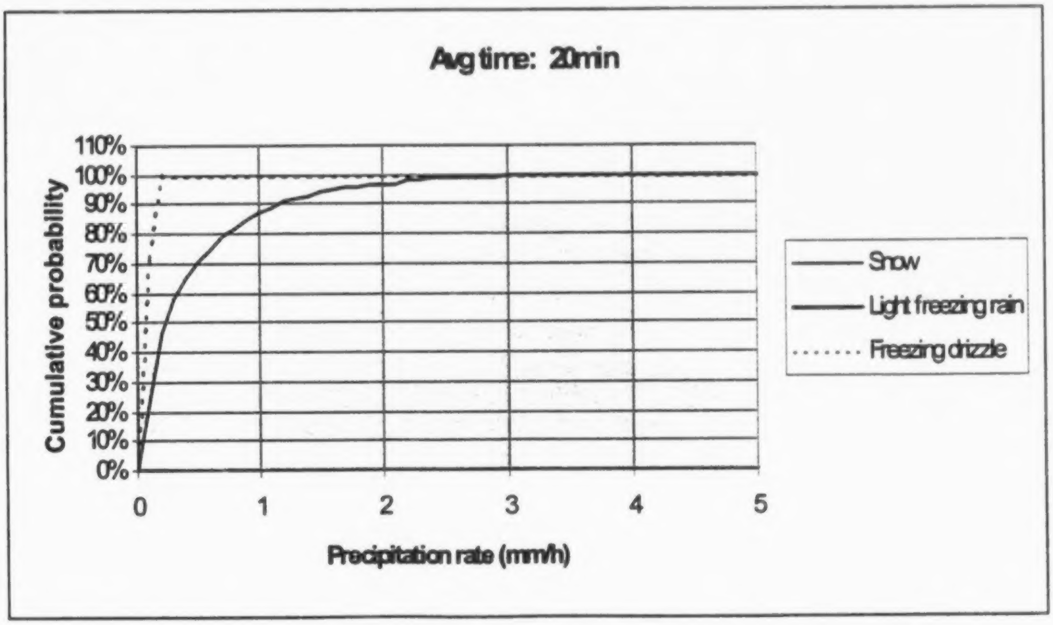

Avg time: 6min
0 to -3C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

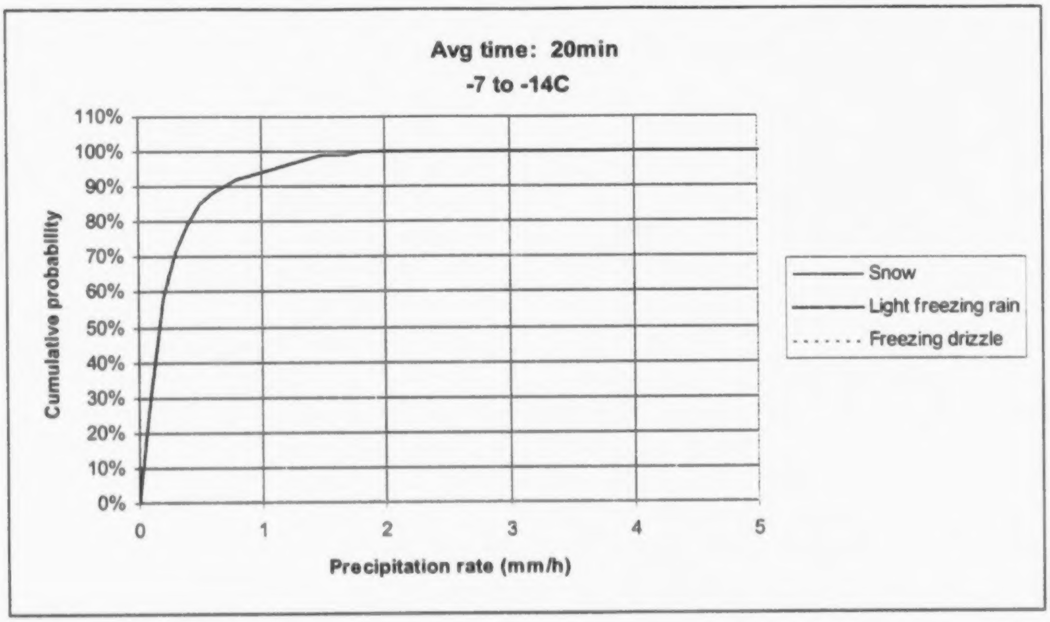

Avg time: 6min
-3 to -7C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

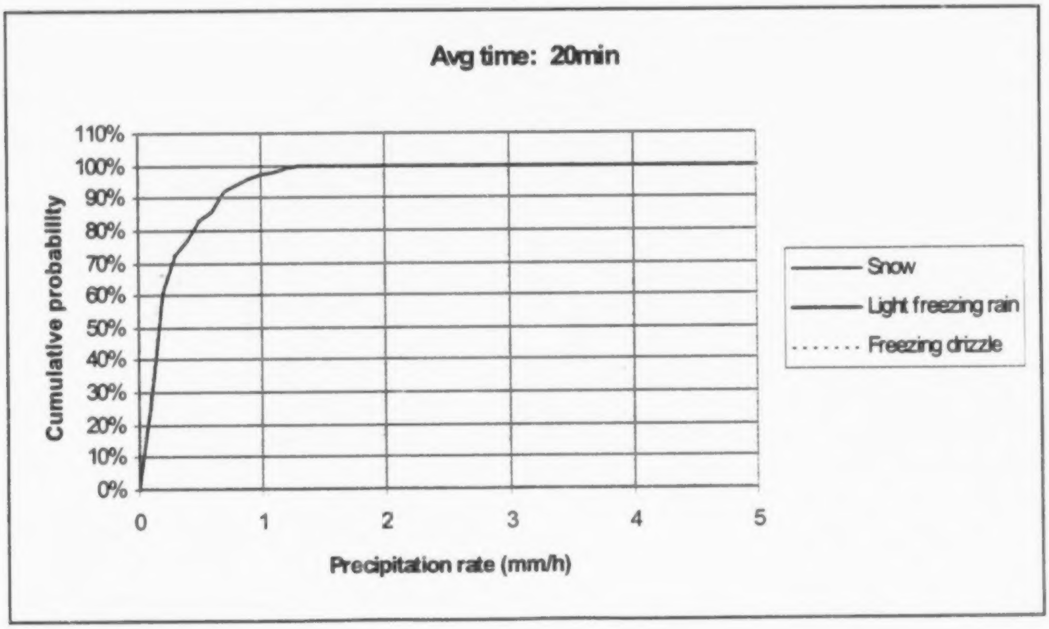

Avg time: 6min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

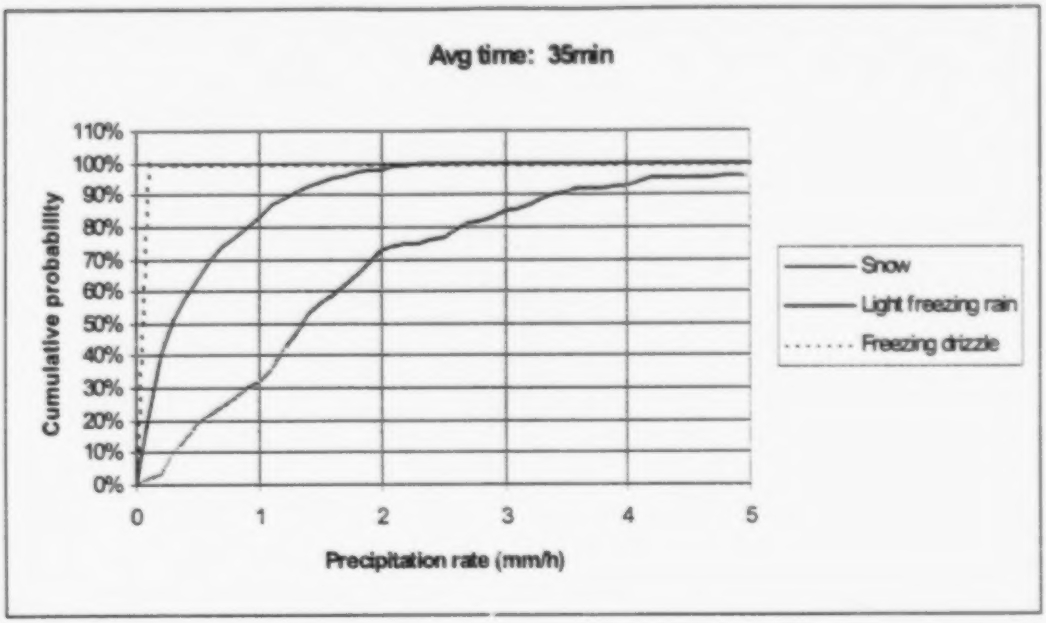

Avg time: 6min
-14 to -25C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

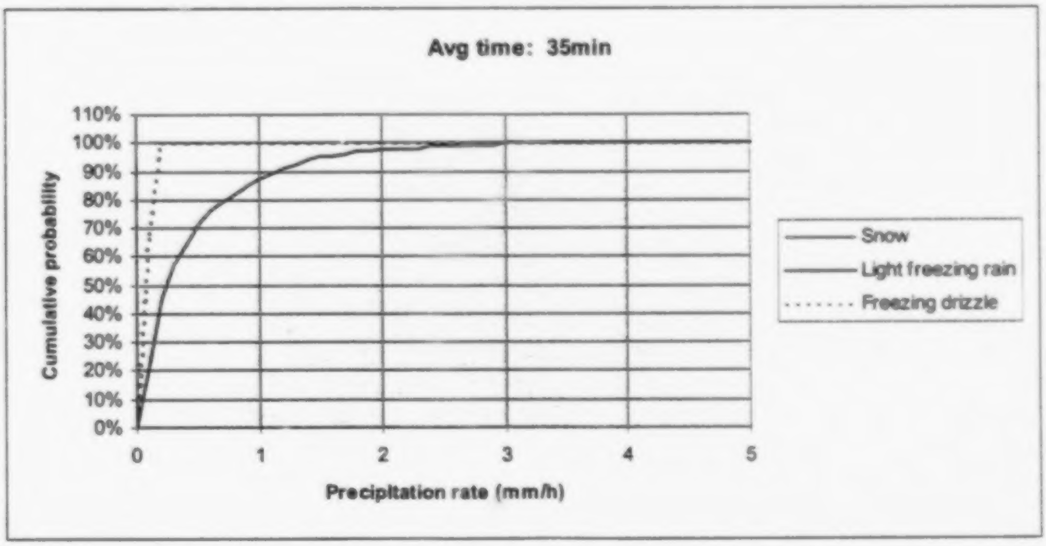

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

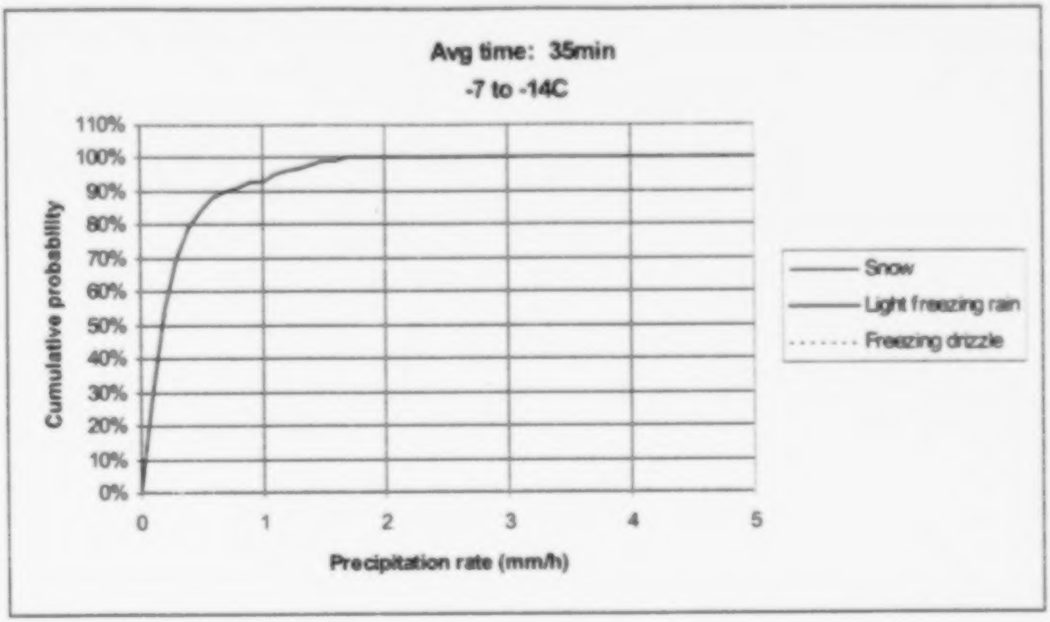

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

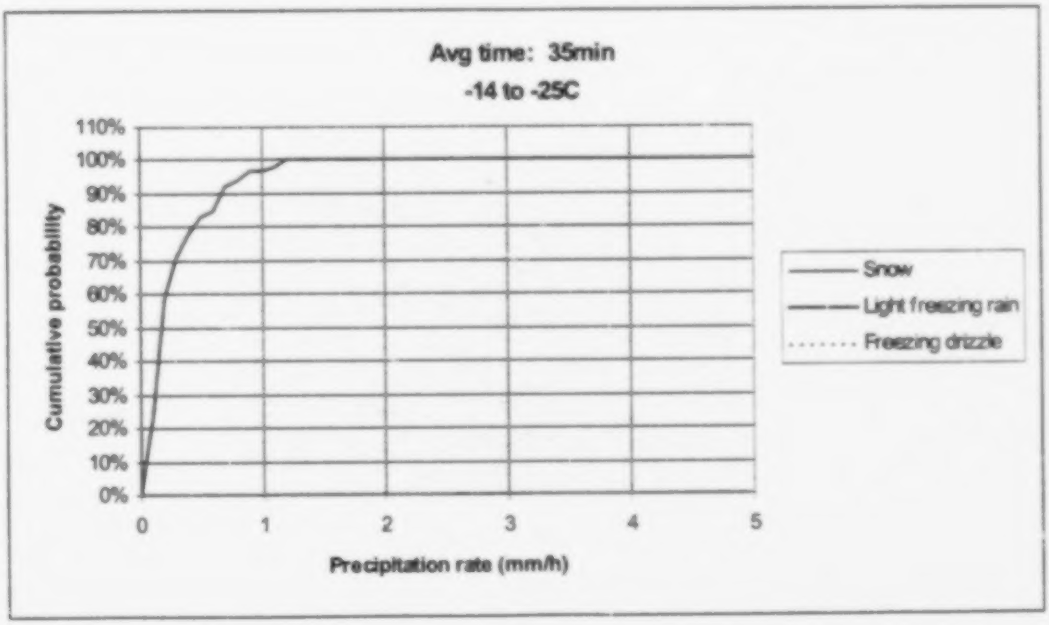

Avg time: 20min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

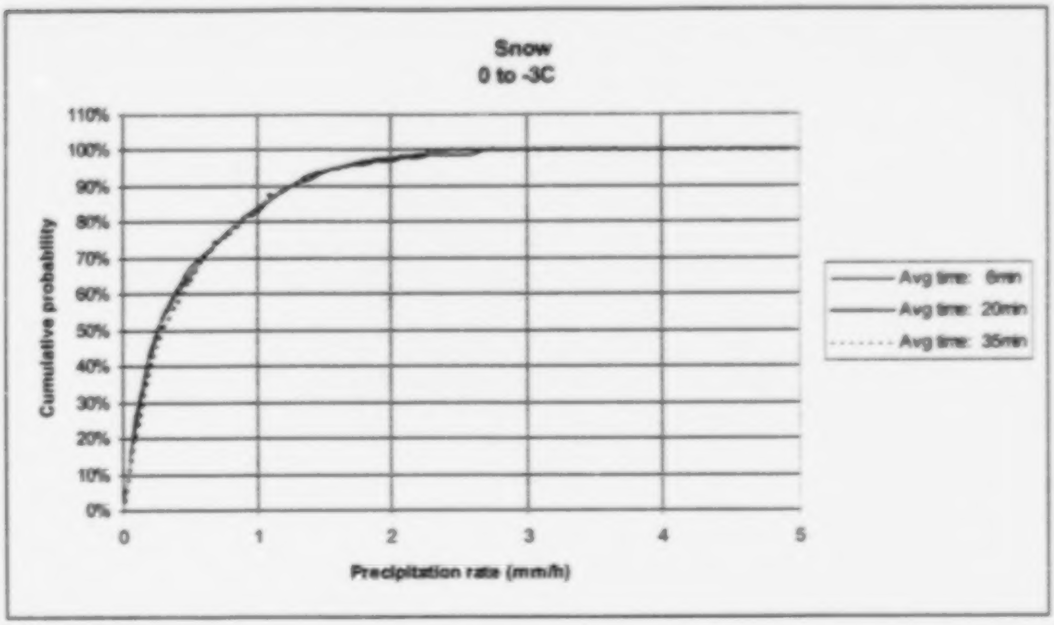

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

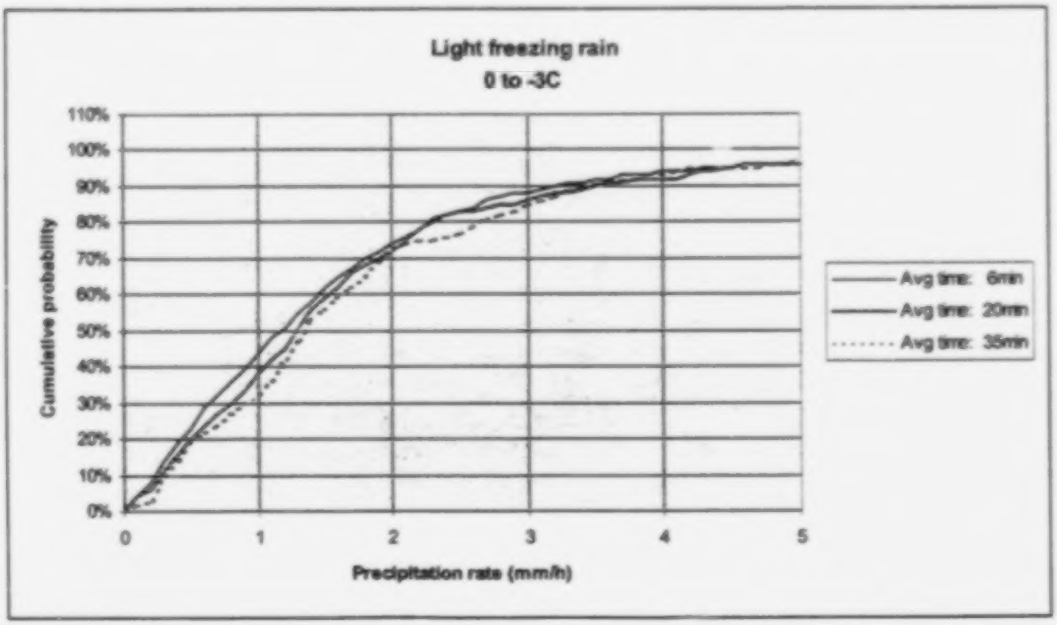

Avg time: 35min
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-7 to -14C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-14 to -25C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Snow
0 to -3C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min


Light freezing rain
0 to -3C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min

# APPENDIX E

# MONTHLY METEOROLOGICAL SUMMARY
MONTREAL - DORVAL

# SOMMAIRE MÉTÉOROLOGIQUE MENSUEL
# MONTHLY METEOROLOGICAL SUMMARY

Environnement Canada
Direction de l'environnement atmosphérique

Environment Canada
Atmospheric Environment Branch

Janvier 2001

## Montreal - Dorval (AUTO)

January 2001

LAT 45°28N LONG 73°45W ALTITUDE 36 METRES (NMM) ELEVATION 36 METRES (ASL) HEURE NORMALE UTILISÉE DE L'EST / STANDARD TIME USED Eastern

| DATE | TEMPÉRATURE / TEMPERATURE: MAXIMALE / MAXIMUM °C | MINIMALE / MINIMUM °C | MOYENNE / MEAN °C | DEGRÉS-JOURS / DEGREE-DAYS: DE CHAUFFE / HEATING Base 18 °C | DE CROISSANCE / GROWING Base 5 °C | DE RÉFRIGÉRATION / COOLING Base 18 °C | HUMIDITÉ REL. / REL. HUMIDITY: MAXIMALE / MAXIMUM % | MINIMALE / MINIMUM % | ORAGE / THUNDERSTORM | PRÉCIPITATIONS / PRECIPITATION: PLUIE (HAUTEUR) / RAINFALL mm | NEIGE (HAUTEUR) / SNOWFALL cm | PRÉCIP. TOTALE / TOTAL PRECIP. mm | NEIGE AU SOL / SNOW ON GROUND cm | VENTS / WINDS: VITESSE MOYENNE / AVERAGE SPEED km/h | DIRECTION DOMINANTE / PREVAILING DIRECTION | VITESSE MOYENNE MAX SUR 2 MIN & DIRECTION / MAX 2 MIN MEAN SPEED & DIRECTION | km/h | INSOLATION EFFECTIVE / BRIGHT SUNSHINE HEURES / HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -7.4 | -11.2 | -9.3 | 27.3 | | | 81 | 68 | | | TR | TR | 20.0 | 25.3 | WSW | W* | 31 | 1.4 |
| 2 | -9.9 | -14.7 | -12.3 | 30.3 | | | 85 | 73 | | | TR | TR | 19.0 | 21.3 | WSW | W | 33 | 2.3 |
| 3 | -2.1 | -11.4 | -6.8 | 24.8 | | | 87 | 66 | | | 0.8 | 0.7 | 16.0 | 12.8 | SSW | S* | 26 | |
| 4 | -3.6 | -16.7 | -10.2 | 28.2 | | | 87 | 62 | | | 0.7 | 0.7 | 15.0 | 17.3 | W | W* | 26 | 0.6 |
| 5 | -5.4 | -18.9 | -12.2 | 30.2 | | | 88 | 71 | | | 5.4 | 5.4 | 15.0 | 16.6 | NE | NE* | 26 | 0.2 |
| 6 | -2.8 | -8.0 | -5.4 | 23.4 | | | 89 | 75 | | | 1.7 | 1.7 | 18.0 | 11.3 | NNE | NNE* | 19 | 0.3 |
| 7 | -2.6 | -8.3 | -5.5 | 23.5 | | | 87 | 67 | | | 0.5 | 0.5 | 18.0 | 6.0 | SW | WSW* | 13 | 4.4 |
| 8 | -4.5 | -6.4 | -5.5 | 23.5 | | | 88 | 79 | | | 4.2 | 3.8 | 17.0 | 12.6 | NE | NE | 22 | |
| 9 | -5.4 | -18.2 | -11.8 | 29.8 | | | 87 | 72 | | | 1.2 | 1.3 | 19.0 | 19.3 | WSW | W | 35 | 0.8 |
| 10 | -10.0 | -19.6 | -14.8 | 32.8 | | | 87 | 59 | | | TR | TR | 21.0 | 13.0 | W | WSW | 24 | 6.4 |
| 11 | -1.2 | -10.4 | -5.8 | 23.8 | | | 91 | 51 | | TR | 0.4 | 0.4 | 17.0 | 17.7 | WNW | WNW | 46 | 5.5 |
| 12 | -8.3 | -16.2 | -12.3 | 30.3 | | | 87 | 59 | | | | | 17.0 | 8.4 | SW | WNW | 17 | 8.6 |
| 13 | -3.7 | -16.2 | -10.0 | 28.0 | | | 88 | 72 | | | | | 16.0 | 5.8 | SW | SW | 15 | 0.7 |
| 14 | 1.1 | -9.2 | -4.1 | 22.1 | | | 86 | 54 | | | | | 16.0 | 16.5 | ENE | ENE | 30 | 0.9 |
| 15 | -7.3 | -11.1 | -9.2 | 27.2 | | | 88 | 63 | | TR | 8.2 | 8.8 | 16.0 | 24.6 | NE | NE | 39 | |
| 16 | -2.2 | -7.5 | -4.9 | 22.9 | | | 90 | 68 | | 0.4 | 2.6 | 2.8 | 22.0 | 12.9 | W | W | 28 | |
| 17 | -6.9 | -18.3 | -12.6 | 30.6 | | | 83 | 70 | | | 2.7 | 1.6 | 24.0 | 10.1 | W | WSW | 15 | 2.9 |
| 18 | -7.0 | -20.7 | -13.9 | 31.9 | | | 86 | 75 | | | TR | TR | 25.0 | 9.0 | NNE | NNW | 19 | 5.3 |
| 19 | 0.4 | -13.9 | -6.8 | 24.8 | | | 89 | 61 | | TR | TR | TR | 25.0 | 10.2 | N | NW | 20 | |
| 20 | -9.9 | -22.2 | -16.1 | 34.1 | | | 81 | 55 | | | | | 23.0 | 7.3 | NNE | NNE* | 20 | 8.4 |
| 21 | -9.1 | -23.6 | -16.4 | 34.4 | | | 87 | 67 | | | 0.5 | 0.3 | 23.0 | 9.1 | W* | WSW* | 17 | |
| 22 | -5.7 | -18.4 | -12.1 | 30.1 | | | 89 | 67 | | | | | 23.0 | 7.3 | S | S* | 13 | 8.6 |
| 23 | 0.4 | -6.8 | -3.2 | 21.2 | | | 91 | 68 | | | TR | TR | 23.0 | 17.5 | S | S | 24 | 0.1 |
| 24 | 1.7 | -2.8 | -0.6 | 18.6 | | | 99 | 74 | | | 4.4 | 2.1 | 22.0 | 10.3 | SW | SW* | 15 | 3.5 |
| 25 | -1.8 | -14.9 | -8.4 | 26.4 | | | 97 | 60 | | | 1.0 | 0.7 | 25.0 | 17.7 | WSW | NNE | 31 | 3.9 |
| 26 | -0.4 | -15.3 | -7.9 | 25.9 | | | 89 | 68 | | | | | 23.0 | 13.4 | SW | SW | 31 | 5.3 |
| 27 | -3.1 | -7.7 | -5.4 | 23.4 | | | 92 | 74 | | | 0.4 | 0.4 | 23.0 | 9.0 | N | NNE | 19 | |
| 28 | -5.8 | -17.3 | -11.6 | 29.6 | | | 86 | 34 | | | TR | TR | 22.0 | 11.6 | W | W | 24 | 8.8 |
| 29 | -1.5 | -19.0 | -10.3 | 28.3 | | | 96 | 67 | | | | | 22.0 | 9.2 | SW | SW | 20 | 0.7 |
| 30 | -2.6 | -12.9 | -7.8 | 25.8 | | | 97 | 88 | | | 8.0 | 12.0 | 22.0 | 21.5 | NE | NE* | 39 | |
| 31 | -3.0 | -8.9 | -6.0 | 24.0 | | | 91 | 83 | | | 5.8 | 5.2 | 29.0 | 22.3 | NNE | NE* | 33 | |
| | MOY. -4.2 MEAN | MOY. -13.8 MEAN | MOY. -9.0 MEAN | TOTAL 837.2 | TOTAL | TOTAL | MOY. 87 MEAN | MOY. 66 MEAN | TOTAL | TOTAL 0.4 | TOTAL 48.5 | TOTAL 48.4 | | MOY. 13.8 MEAN | DOMINANTE W PREVAILING | MAXIMALE WNW | 46 MAXIMUM | TOTAL 79.6 |
| NORMALE NORMAL | -5.8 | -14.9 | -10.3 | 879.6 | 0.1 | 0.0 | | | | 20.8 | 47.7 | 63.3 | | 17.0 | W | | | 102.9 |

### SOMMAIRE DE DEGRÉS-JOURS/DEGREE-DAY SUMMARY

| AU-DESSOUS DE 18°C BELOW 18°C | ANNÉE EN COURS THIS YEAR | NORMALE NORMAL | AU-DESSUS DE 5°C ABOVE 5°C | ANNÉE EN COURS THIS YEAR | NORMALE NORMAL |
|---|---|---|---|---|---|
| TOTAL DU MOIS TOTAL FOR MONTH | 837.2 | 879.6 | TOTAL DU MOIS TOTAL FOR MONTH | | 0.1 |
| ACCUMULÉS DEPUIS LE 1ER JUILLET ACCUMULATED SINCE JULY 1st | 2573.2 | 2600.9 | ACCUMULÉS DEPUIS LE 1ER AVRIL ACCUMULATED SINCE APRIL 1st | 2028.3 | 2071.8 |

| JOURS AVEC PRÉCIPITATIONS TOTALES / DAYS WITH TOTAL PRECIPITATION mm: 0.2 OU PLUS OR MORE | 1.0 OU PLUS OR MORE | 2.0 OU PLUS OR MORE | 10.0 OU PLUS OR MORE | 25.0 OU PLUS OR MORE | JOURS AVEC CHUTES DE NEIGE / DAYS WITH SNOWFALL cm: 0.2 OU PLUS OR MORE | 1.0 OU PLUS OR MORE | 2.0 OU PLUS OR MORE | 10.0 OU PLUS OR MORE | 25.0 OU PLUS OR MORE |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 10 | 7 | 1 | | 17 | 11 | 8 | | |

1. Normale/Normal 1961-1990
2. Journée climatologique/Climatological Day (01h00HNE à/to 01H00HNE)
3. (AUTO): mesures d'une station automatique/data from automatic station
4. TR=Trace M=Manquant/Missing E=Estimé/Estimated C=Calme/Calm
5. Pas de valeur/No entry=Pas d'événement/No occurrence
6. *=indique la première de plusieurs valeurs valides/indicates first of many valid values
7. c = correction

Données non contrôlées/Data is not validated
Les précipitations ont un seuil mesurable de 1,0 mm
Measurable threshold of precipitation is 1,0 mm

## Montreal - Dorval (AUTO) [illegible] Janvier 2001 January 2001

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 1.7 | 24 | 6.6 | 3 | | 13.9 | 25 | 1950 | | | | 60 |
| [illegible] | -23.6 | 21 | -26.0 | 16 | | | | | -37.8 | 15 | 1957 | 60 |
| [illegible] | -9.0 | | -10.1 | | -10.3 | -3.6 | | 1990 | -16.5 | | 1994 | 60 |
| [illegible] | 0.4 | | 20.0 | | 20.8 | 82.7 | 0 | 1964 | 0.0 | | 1987 | 60 |
| [illegible] | 48.5 | | 64.8 | | 47.7 | 95.1 c | 0 | 1999 | 11.2 | | 1980 | 60 |
| [illegible] | 48.4 | | 95.8 | | 63.3 | 128.5 | 0 | 1947 | 12.5 | | 1964 | 60 |
| [illegible] | 17 | | 15 | | 16 | 22 | 0 | 1990 | 6 c | | 1980 | 60 |
| [illegible] | 0.4 | 16 | 8.2 | 10 | | 31.0 | 20 | 1964 | | | | 60 |
| [illegible] | 8.2 | 15 | 14.6 | 16 | | 32.8 | 21 | 1979 | | | | 60 |
| [illegible] | 12.0 | 30 | 35.8 | 10 | | 35.0 | 29 | 1983 | | | | 60 |
| [illegible] | | | | | | | | | | | | |
| [illegible] | | | | | | 1.6 | 14 | 1992 | | | | 34 |
| [illegible] | | | | | | 2.4 | 23 | 1992 | | | | 34 |
| [illegible] | | | | | | 10.1 | 21 | 1983 | | | | 34 |
| [illegible] | | | | | | 10.1 | 21 | 1983 | | | | 34 |
| [illegible] | | | | | | 12.6 | 21 | 1983 | | | | 34 |
| [illegible] | | | | | | | | | | | | |
| [illegible] | 13.8 | | 16.9 | | 17.0 | 22.0 | | 1959 | 11.5 | | 1987 | 48 |
| [illegible] | WNW 46 | 11 | SW 67 | 4 | | SW 90 | 22 | 1959 | | | | 48 |
| [illegible] | WNW 61 | 11 | WSW [illegible] | 4 | | SW 117 | 22 | 1959 | | | | 48 |
| [illegible] | 79.6 | | 113.5 | | 102.9 | 141.3 | | 1980 | 65.8 | | 1979 | 28 |
| [illegible] | 101.15 | | 101.27 | | 101.17 | 102.07 | | 1968 | 100.38 | | 1977 | 44 |
| [illegible] | 102.67 | 22 | 103.57 | 15 | | 104.38 | 26 | 1994 | | | | 44 |
| [illegible] | 99.01 | 30 | 98.39 | 10 | | | | | 96.23 | 26 | 1978 | 44 |

DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRES ANNÉES
CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | A.S.N. S.A.S. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 4.6 | -27.7 | -11.0 | 64.0 | 31.5 | 92.5 | 14.8 | SW 54 | 89.2 | 900.0 | | | 86.5 |
| 1993 | 7.6 | -25.0 | -8.8 | 76.6 | 43.0 | 118.6 | 13.3 | W 46 | 99.1 | 831.5 | | | 65.2 |
| 1994 | 8.1 | -31.8 | -16.5 | 20.6 | 69.2 | 88.8 | 17.1 | NNE 52 | 127.5 | 1069.2 | | | 133.4 |
| 1995 | 10.9 | -33.8 | -6.6 | 63.6 | 55.9 | 114.4 | 16.1 | WSW 48 | 71.6 | 751.8 | | | 103.3 |
| 1996 | 13.1 | -28.0 | -10.7 | 45.6 | 24.2 | 67.4 | 15.2 | SSE 56 | 119.4 | 896.0 | 1.5 | | 156.7 |
| 1997 | 6.7 | -28.8 | -10.4 | 35.0 | 83.8 | 120.0 | 19.8 | WSW 57 | 92.3 | 881.8 | | | 135.8 |
| 1998 | 7.0 | -25.0 | -7.3 | 43.8 | 65.0 | 158.4 | 15.4 | W 39 | 88.7 | 785.7 | 0.6 | | 163.2 |
| 1999 | 9.0 | -27.3 | -9.2 | 31.2 | 95.1 | 148.1 | 17.1 | WSW 41 | 110.5 | 843.9 | | | 107.3 |
| 2000 | 8.6 | -26.0 | -10.1 | 20.0 | 64.8 | 95.8 | 18.9 | SW 67 | 113.5 | 870.4 | | | 87.2 |
| 2001 | 1.7 | -23.6 | -9.0 | 0.4 | 48.5 | 48.4 | 13.8 | WNW 46 | 79.6 | 837.2 | | | 144.6 |

Note: * Nouveau record / New record A.S.N.= Accumulation saisonnière de neige / S.A.S.= Season accumulation snowfall

## Température/Temperature

**Température horaire**
**Hourly temperature**

**Montreal - Dorval (AUTO)**

**Janvier 2001**
**January 2001**

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -63 | -75 | -81 | -92 | -94 | -91 | -101 | -104 | -104 | -106 | -104 | -101 | -97 | -96 | -91 | -91 | -92 | -96 | -97 | -97 | -102 | -103 | -104 | -103 |
| 2 | -109 | -112 | -111 | -120 | -132 | -133 | -141 | -142 | -137 | -132 | -127 | -121 | -116 | -126 | -120 | -121 | -120 | -121 | -118 | -115 | -111 | -109 | -107 | -103 |
| 3 | -100 | -100 | -98 | -100 | -106 | -104 | -111 | -91 | -80 | -75 | -67 | -58 | -45 | -38 | -32 | -28 | -27 | -31 | -31 | -26 | -29 | -30 | -38 | -42 |
| 4 | -39 | -36 | -47 | -50 | -54 | -56 | -56 | -56 | -58 | -61 | -62 | -61 | -56 | -58 | -55 | -57 | -62 | -68 | -81 | -95 | -104 | -130 | -123 | -145 |
| 5 | -162 | -155 | -153 | -129 | -114 | -117 | -120 | -115 | -112 | -111 | -115 | -101 | -88 | -58 | -75 | -79 | -74 | -75 | -81 | -72 | -76 | -78 | -75 | -76 |
| 6 | -81 | -80 | -76 | -73 | -69 | -68 | -67 | -65 | -65 | -56 | -47 | -48 | -48 | -46 | -32 | -38 | -38 | -41 | -39 | -39 | -38 | -38 | -42 | -39 |
| 7 | -41 | -43 | -45 | -48 | -53 | -56 | -57 | -64 | -64 | -62 | -61 | -59 | -48 | -40 | -36 | -43 | -47 | -63 | -58 | -60 | -56 | -50 | -47 | -43 |
| 8 | -45 | -46 | -48 | -52 | -52 | -51 | -51 | -55 | -57 | -59 | -61 | -62 | -62 | -63 | -60 | -55 | -54 | -54 | -54 | -55 | -55 | -54 | -54 | -51 |
| 9 | -55 | -54 | -58 | -62 | -72 | -88 | -100 | -121 | -134 | -139 | -145 | -146 | -141 | -142 | -140 | -137 | -139 | -133 | -133 | -137 | -139 | -139 | -142 | -151 |
| 10 | -158 | -179 | -187 | -188 | -174 | -180 | -188 | -181 | -182 | -173 | -162 | -158 | -148 | -142 | -132 | -125 | -125 | -127 | -130 | -134 | -141 | -129 | -116 | -114 |
| 11 | -107 | -100 | -88 | -80 | -82 | -103 | -93 | -84 | -77 | -60 | -43 | -24 | -27 | -25 | -28 | -32 | -42 | -50 | -69 | -71 | -87 | -71 | -68 | -77 |
| 12 | -82 | -85 | -92 | -105 | -116 | -140 | -140 | -141 | -141 | -140 | -115 | -104 | -100 | -93 | -91 | -88 | -86 | -96 | -104 | -121 | -113 | -125 | -134 | -148 |
| 13 | -134 | -135 | -132 | -134 | -137 | -130 | -144 | -143 | -128 | -118 | -97 | -84 | -83 | -78 | -75 | -68 | -63 | -61 | -58 | -54 | -57 | -54 | -51 | -48 |
| 14 | -41 | -38 | -26 | -26 | -26 | -20 | -17 | -14 | -11 | -8 | -6 | 0 | 2 | -1 | 6 | 3 | -3 | -31 | -40 | -51 | -58 | -61 | -71 | -75 |
| 15 | -83 | -92 | -100 | -103 | -108 | -110 | -107 | -105 | -109 | -109 | -103 | -97 | -98 | -95 | -91 | -90 | -88 | -84 | -79 | -76 | -78 | -81 | -79 | -76 |
| 16 | -76 | -74 | -70 | -68 | -67 | -66 | -62 | -58 | -48 | -48 | -50 | -47 | -42 | -35 | -30 | -26 | -24 | -24 | -24 | -26 | -28 | -32 | -38 | -45 |
| 17 | -58 | -72 | -90 | -107 | -107 | -95 | -97 | -96 | -98 | -102 | -104 | -104 | -103 | -103 | -108 | -98 | -105 | -112 | -123 | -123 | -133 | -140 | -154 | -160 |
| 18 | -160 | -173 | -185 | -180 | -178 | -200 | -205 | -170 | -163 | -139 | -151 | -118 | -107 | -127 | -115 | -99 | -107 | -103 | -88 | -91 | -112 | -106 | -102 | -99 |
| 19 | -91 | -90 | -91 | -87 | -82 | -77 | -71 | -63 | -50 | -43 | -23 | -16 | -13 | -2 | -2 | -5 | -8 | -16 | -28 | -46 | -69 | -88 | -99 | -122 |
| 20 | -127 | -139 | -148 | -157 | -164 | -177 | -177 | -179 | -179 | -177 | -164 | -130 | -147 | -142 | -124 | -122 | -141 | -147 | -162 | -192 | -168 | -175 | -217 | -190 |
| 21 | -190 | -215 | -204 | -227 | -220 | -207 | -219 | -201 | -210 | -209 | -188 | -174 | -152 | -137 | -121 | -110 | -104 | -100 | -98 | -96 | -94 | -92 | -95 | -103 |
| 22 | -112 | -114 | -119 | -114 | -134 | -144 | -155 | -177 | -140 | -130 | -115 | -110 | -103 | -99 | -94 | -95 | -96 | -113 | -111 | -108 | -106 | -93 | -84 | -74 |
| 23 | -70 | -58 | -39 | -43 | -51 | -58 | -64 | -49 | -47 | -40 | -32 | -28 | -12 | -2 | 2 | 2 | 2 | 0 | -2 | 2 | 2 | 0 | 0 | 0 |
| 24 | -2 | -4 | -3 | -5 | -8 | -8 | -13 | -9 | -6 | -3 | -4 | -2 | 3 | 10 | 11 | 10 | 11 | 2 | -9 | -15 | -22 | -9 | -15 | -13 |
| 25 | -16 | -18 | -28 | -32 | -44 | -47 | -52 | -62 | -71 | -74 | -76 | -80 | -77 | -86 | -88 | -93 | -95 | -100 | -107 | -114 | -118 | -123 | -126 | -145 |
| 26 | -129 | -148 | -125 | -113 | -111 | -83 | -90 | -94 | -96 | -93 | -66 | -51 | -37 | -23 | -7 | -9 | -15 | -21 | -27 | -39 | -33 | -49 | -51 | -50 |
| 27 | -48 | -53 | -47 | -51 | -51 | -54 | -56 | -64 | -74 | -71 | -73 | -62 | -53 | -45 | -39 | -32 | -36 | -37 | -43 | -42 | -48 | -47 | -45 | -42 |
| 28 | -50 | -59 | -74 | -87 | -97 | -110 | -126 | -135 | -146 | -136 | -133 | -118 | -109 | -96 | -91 | -89 | -90 | -107 | -99 | -111 | -107 | -126 | -123 | -139 |
| 29 | -153 | -168 | -180 | -155 | -156 | -184 | -149 | -167 | -156 | -104 | -91 | -72 | -57 | -46 | -36 | -24 | -27 | -17 | -24 | -30 | -43 | -42 | -48 | -58 |
| 30 | -64 | -77 | -86 | -100 | -94 | -112 | -78 | -59 | -45 | -47 | -42 | -41 | -38 | -47 | -50 | -50 | -45 | -38 | -37 | -35 | -31 | -28 | -28 | -28 |
| 31 | -28 | -32 | -39 | -45 | -47 | -51 | -54 | -57 | -62 | -68 | -69 | -71 | -73 | [illegible] | -79 | -83 | -85 | -87 | -89 | -88 | -88 | -86 | -86 | -88 |

Unités / Units: 0.1 °C M = Manquant /Missing

Lire / Read -123 = -12.3 °C -1 = -0.1 °C 0 = 0.0 °C 12 = +1.2 °C 123 = +12.3 °C

Heure normale locale: Est Local standard time: Eastern

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Courrier électronique/Email: Climat.Quebec@ec.gc.ca
Renseignements climatologiques / Climate Informations :1-900-565-1111

## Vents/Winds

Vents horaires (km/h)
Hourly winds (km/h)

**Montreal - Dorval (AUTO)**

Janvier 2001
January 2001

Heure normale locale: Est
Local standard time : Eastern

| Date | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | Rafale max<br>Peak Gust | Heure<br>Hour | Jour<br>Day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | W<br>26 | W<br>22 | W<br>28 | W<br>24 | W<br>28 | W<br>31 | WSW<br>24 | WSW<br>28 | W<br>28 | W<br>28 | W<br>30 | W<br>30 | WSW<br>31 | WSW<br>30 | WSW<br>28 | WSW<br>24 | W<br>24 | WSW<br>26 | WSW<br>26 | WSW<br>24 | WSW<br>20 | WSW<br>22 | W<br>15 | WSW<br>17 | W<br>41 | 10 | 1 |
| 2 | W<br>22 | WSW<br>20 | WSW<br>15 | WSW<br>15 | WSW<br>13 | W<br>19 | SW<br>13 | WSW<br>17 | W<br>19 | W<br>24 | W<br>28 | WSW<br>26 | W<br>31 | WSW<br>30 | WSW<br>28 | W<br>33 | WSW<br>28 | WSW<br>26 | WSW<br>31 | WSW<br>31 | WSW<br>19 | W<br>17 | W<br>15 | W<br>15 | WSW<br>48 | 16 | 2 |
| 3 | W<br>11 | W<br>6 | W<br>7 | WSW<br>7 | NW<br>4 | C<br>0 | SW<br>6 | C<br>0 | S<br>6 | SSE<br>9 | S<br>9 | SSW<br>9 | SSW<br>13 | SW<br>13 | SSW<br>11 | SSW<br>15 | SSW<br>15 | SSE<br>15 | SSW<br>22 | SSW<br>20 | SSW<br>15 | SSW<br>13 | S<br>26 | S<br>22 | SW<br>46 | 22 | 3 |
| 4 | SSW<br>26 | SW<br>24 | WSW<br>22 | SW<br>15 | W<br>22 | WSW<br>20 | WSW<br>20 | SW<br>20 | WSW<br>15 | WSW<br>19 | W<br>24 | W<br>24 | W<br>20 | W<br>24 | W<br>26 | W<br>26 | W<br>22 | W<br>19 | NW<br>13 | NW<br>13 | NW<br>17 | NW<br>13 | WSW<br>7 | SW<br>6 | WSW<br>35 | 4 | 4 |
| 5 | SW<br>9 | C<br>0 | ENE<br>4 | NE<br>7 | E<br>13 | E<br>11 | E<br>15 | ENE<br>17 | NE<br>19 | ENE<br>19 | NE<br>19 | NE<br>22 | NE<br>20 | ENE<br>20 | NNE<br>19 | NE<br>26 | NE<br>22 | NE<br>26 | NE<br>19 | NNE<br>15 | NNE<br>15 | NNE<br>11 | NNE<br>9 | NNE<br>15 | E<br>35 | 13 | 5 |
| 6 | NNE<br>17 | NNE<br>19 | NNE<br>19 | NNE<br>17 | NNE<br>15 | NNE<br>13 | NNE<br>17 | NNE<br>17 | NE<br>19 | NE<br>17 | NNE<br>11 | NNE<br>15 | NNE<br>19 | NE<br>13 | NNE<br>13 | N<br>11 | ENE<br>6 | NNW<br>11 | NNW<br>4 | C<br>0 | C<br>0 | SW<br>9 | NW<br>4 | SW<br>7 |  |  |  |
| 7 | W<br>6 | WSW<br>9 | WSW<br>13 | WSW<br>7 | W<br>7 | W<br>6 | SW<br>7 | SW<br>9 | SW<br>6 | C<br>0 | SW<br>13 | SSW<br>7 | SW<br>7 | SSW<br>6 | C<br>0 | NE<br>4 | C<br>0 | S<br>4 | C<br>0 | C<br>0 | NNE<br>7 | N<br>4 | ESE<br>6 | E<br>9 |  |  |  |
| 8 | ENE<br>9 | NE<br>13 | NE<br>11 | NE<br>11 | NE<br>15 | NE<br>19 | NE<br>19 | NE<br>20 | NNE<br>19 | NNE<br>20 | NE<br>22 | NNE<br>19 | NNE<br>19 | NNE<br>17 | N<br>15 | NNW<br>11 | N<br>7 | N<br>7 | N<br>7 | NW<br>4 | NW<br>4 | WNW<br>4 | W<br>6 | SW<br>6 |  |  |  |
| 9 | SSW<br>9 | SSW<br>11 | SW<br>9 | WSW<br>11 | WSW<br>20 | W<br>24 | W<br>22 | WSW<br>19 | WSW<br>20 | W<br>22 | WSW<br>20 | SW<br>28 | WSW<br>24 | WSW<br>31 | WSW<br>28 | W<br>35 | WSW<br>20 | W<br>19 | WNW<br>13 | NW<br>11 | WNW<br>11 | WNW<br>17 | NW<br>24 | WNW<br>17 | WSW<br>44 | 13 | 9 |
| 10 | W<br>9 | W<br>9 | W<br>13 | WNW<br>13 | W<br>13 | W<br>15 | W<br>13 | W<br>20 | W<br>13 | WSW<br>13 | W<br>13 | W<br>20 | WSW<br>15 | WSW<br>22 | W<br>20 | WSW<br>24 | W<br>19 | WSW<br>9 | SW<br>7 | SSW<br>9 | SSE<br>7 | SW<br>4 | SE<br>7 | E<br>7 | WSW<br>33 | 15 | 10 |
| 11 | ESE<br>4 | SE<br>11 | SSE<br>13 | SW<br>4 | WNW<br>7 | NNW<br>4 | W<br>9 | W<br>15 | W<br>17 | WSW<br>13 | W<br>19 | WNW<br>30 | NW<br>26 | WNW<br>46 | WNW<br>35 | NW<br>22 | WNW<br>26 | WNW<br>22 | NW<br>7 | WNW<br>15 | WNW<br>7 | WNW<br>19 | NW<br>19 | W<br>17 | WNW<br>61 | 13 | 11 |
| 12 | WNW<br>17 | W<br>15 | WNW<br>17 | WNW<br>15 | NW<br>13 | NW<br>13 | NW<br>7 | NNW<br>7 | C<br>0 | C<br>0 | SSW<br>11 | SW<br>9 | S<br>9 | WSW<br>9 | SW<br>6 | SW<br>7 | SW<br>13 | SW<br>11 | SW<br>7 | SW<br>6 | SW<br>9 | SW<br>6 | SSW<br>7 | SW<br>6 |  |  |  |
| 13 | SW<br>7 | SSW<br>6 | SW<br>6 | SSW<br>4 | SW<br>6 | SSW<br>11 | WSW<br>6 | S<br>4 | ESE<br>6 | C<br>0 | C<br>0 | C<br>0 | ESE<br>13 | SSE<br>7 | NE<br>6 | NE<br>7 | C<br>0 | C<br>0 | W<br>7 | SW<br>6 | SW<br>15 | WSW<br>11 | SW<br>7 | SSW<br>6 |  |  |  |
| 14 | WSW<br>4 | W<br>7 | W<br>17 | W<br>15 | W<br>11 | WNW<br>7 | W<br>9 | WSW<br>7 | W<br>15 | W<br>15 | W<br>9 | WNW<br>13 | NNW<br>6 | W<br>11 | WSW<br>9 | ENE<br>15 | NE<br>20 | ENE<br>22 | ENE<br>19 | ENE<br>28 | ENE<br>26 | ENE<br>20 | ENE<br>22 | ENE<br>26 | ENE<br>33 | 17 | 14 |
| 15 | ENE<br>30 | ENE<br>24 | NE<br>31 | NE<br>39 | NE<br>20 | NE<br>30 | NE<br>24 | NNE<br>26 | NNE<br>24 | NE<br>28 | NE<br>26 | NE<br>28 | NE<br>24 | NE<br>26 | NE<br>26 | NE<br>30 | NE<br>30 | NNE<br>20 | NE<br>24 | NNE<br>20 | NNE<br>19 | NNE<br>24 | NNE<br>19 | NNE<br>19 | NE<br>46 | 4 | 15 |
| 16 | NNE<br>17 | NNE<br>17 | NNE<br>11 | N<br>6 | NNW<br>6 | N<br>7 | NNE<br>6 | N<br>6 | C<br>0 | W<br>4 | WNW<br>7 | W<br>6 | W<br>11 | W<br>13 | W<br>13 | W<br>20 | W<br>28 | WNW<br>20 | W<br>20 | W<br>22 | W<br>19 | W<br>20 | WNW<br>19 | WNW<br>15 | W<br>33 | 16 | 16 |
| 17 | NW<br>17 | NW<br>13 | W<br>9 | WNW<br>9 | WNW<br>7 | WNW<br>13 | WNW<br>4 | W<br>6 | W<br>7 | W<br>13 | W<br>13 | W<br>11 | W<br>13 | W<br>13 | W<br>11 | W<br>13 | WSW<br>11 | SW<br>11 | WSW<br>15 | SW<br>13 | WSW<br>11 | WSW<br>13 | SSW<br>7 | SW<br>9 |  |  |  |
| 18 | SW<br>7 | SSW<br>4 | WSW<br>4 | C<br>0 | NE<br>4 | C | C<br>0 | NNE<br>7 | NE<br>11 | NNE<br>7 | NNE<br>7 | SE<br>9 | N<br>7 | NNE<br>13 | NE<br>15 | N<br>11 | NNE<br>17 | N<br>15 | N<br>9 | NNW<br>19 | NNE<br>17 | NNE<br>11 | N<br>11 | NNE<br>7 |  |  |  |
| 19 | N<br>7 | N<br>9 | NNE<br>7 | NNE<br>6 | N<br>6 | N<br>4 | NNW<br>6 | C<br>0 | WSW<br>4 | WSW<br>4 | WSW<br>7 | SSW<br>13 | W<br>4 | WSW<br>13 | W<br>11 | WNW<br>15 | W<br>15 | W<br>19 | NW<br>15 | NW<br>20 | NW<br>17 | N<br>17 | N<br>11 | N<br>11 |  |  |  |
| 20 | NNE<br>7 | NNE<br>13 | NNE<br>20 | NNE<br>20 | NE<br>13 | NNE<br>11 | NNE<br>7 | NNE<br>9 | NE<br>9 | NNE<br>11 | N<br>7 | S<br>6 | C<br>0 | W<br>4 | C<br>0 | SW<br>7 | SSW<br>9 | SW<br>7 | C<br>0 | W<br>6 | C<br>0 | NNW<br>6 | NW<br>6 | N<br>6 |  |  |  |
| 21 | NNW<br>6 | WNW<br>4 | W<br>4 | C<br>0 | NNW<br>9 | SW<br>9 | C<br>0 | SW<br>6 | NW<br>6 | NW<br>4 | SW<br>11 | SSW<br>15 | SW<br>9 | SW<br>11 | WSW<br>15 | WSW<br>15 | WSW<br>17 | WSW<br>15 | W<br>7 | W<br>11 | WNW<br>17 | W<br>11 | W<br>11 | WNW<br>7 |  |  |  |
| 22 | C<br>0 | NW<br>9 | N<br>9 | NE<br>7 | NNE<br>11 | NNE<br>7 | NE<br>7 | NE<br>7 | ESE<br>7 | ESE<br>6 | C<br>0 | C<br>0 | S<br>13 | SSW<br>9 | W<br>7 | SSW<br>4 | SW<br>6 | S<br>9 | S<br>13 | SSW<br>6 | SE<br>11 | SSE<br>7 | ESE<br>7 | ESE<br>6 |  |  |  |
| 23 | S<br>6 | S<br>11 | S<br>13 | S<br>17 | S<br>19 | S<br>15 | S<br>11 | S<br>22 | S<br>22 | S<br>24 | S<br>20 | S<br>17 | S<br>20 | SW<br>20 | W<br>19 | WSW<br>20 | WSW<br>20 | SW<br>19 | SW<br>20 | SW<br>17 | SW<br>17 | SW<br>15 | SW<br>13 | SW<br>11 | S<br>33 | 10 | 23 |
| 24 | SW<br>15 | SW<br>13 | SW<br>15 | SSW<br>11 | SW<br>13 | SW<br>9 | SSW<br>9 | SSW<br>13 | SW<br>9 | SW<br>13 | WSW<br>15 | W<br>15 | W<br>15 | W<br>15 | W<br>9 | WSW<br>13 | SW<br>11 | WSW<br>9 | WSW<br>7 | W<br>6 | WNW<br>4 | SW<br>9 | SW<br>11 | SW<br>9 |  |  |  |
| 25 | C<br>0 | N<br>7 | NNE<br>13 | NNE<br>24 | NNE<br>31 | N<br>26 | N<br>20 | NNE<br>20 | N<br>19 | NNE<br>17 | N<br>15 | N<br>9 | W<br>15 | W<br>19 | W<br>19 | WSW<br>19 | WSW<br>28 | WSW<br>22 | WSW<br>26 | W<br>20 | W<br>19 | WSW<br>15 | SW<br>13 | C<br>0 | NNE<br>37 | 4 | 25 |
| 26 | SW<br>9 | WSW<br>6 | SW<br>13 | W<br>6 | SW<br>4 | WSW<br>19 | SW<br>13 | SW<br>9 | SW<br>15 | S<br>15 | SW<br>17 | SW<br>13 | SW<br>17 | SW<br>11 | SW<br>31 | SW<br>28 | SW<br>26 | SW<br>22 | WSW<br>20 | S<br>7 | SW<br>7 | S<br>4 | S<br>6 | SSE<br>7 | SW<br>41 | 15 | 26 |
| 27 | SE<br>4 | SSE<br>7 | E<br>4 | SE<br>4 | NE<br>6 | NE<br>7 | ESE<br>6 | N<br>6 | N<br>9 | N<br>13 | NNE<br>19 | NNE<br>13 | N<br>7 | N<br>11 | NW<br>4 | WNW<br>4 | W<br>9 | SW<br>11 | SW<br>11 | SW<br>11 | W<br>6 | NW<br>7 | WNW<br>9 | WNW<br>11 |  |  |  |
| 28 | W<br>13 | W<br>15 | W<br>17 | W<br>19 | W<br>24 | W<br>19 | W<br>19 | SW<br>11 | SSW<br>6 | SSW<br>7 | WSW<br>11 | SW<br>9 | W<br>19 | W<br>17 | SSW<br>13 | SSW<br>17 | SW<br>13 | W<br>13 | WSW<br>11 | W<br>11 | WSW<br>7 | SW<br>7 | SW<br>9 | C<br>0 |  |  |  |
| 29 | C<br>0 | C<br>0 | SW<br>6 | SW<br>7 | SSW<br>7 | WSW<br>4 | C<br>0 | C<br>0 | N<br>4 | SE<br>13 | SSE<br>13 | SSE<br>15 | C<br>0 | S<br>9 | SW<br>9 | SW<br>9 | SW<br>9 | SW<br>13 | SW<br>11 | WSW<br>15 | WSW<br>17 | SW<br>20 | WSW<br>15 | SW<br>11 |  |  |  |
| 30 | SSW<br>4 | SSW<br>9 | SSW<br>4 | S<br>4 | S<br>4 | SE<br>6 | E<br>4 | E<br>9 | E<br>11 | E<br>17 | NE<br>22 | NE<br>24 | NE<br>30 | NE<br>26 | NE<br>39 | NE<br>35 | NE<br>39 | NE<br>35 | NE<br>37 | NNE<br>35 | NNE<br>31 | NNE<br>31 | N<br>17 | N<br>17 | NE<br>56 | 16 | 30 |
| 31 | N<br>19 | NNE<br>20 | N<br>22 | N<br>22 | NNE<br>24 | NNE<br>22 | NNE<br>19 | NE<br>22 | NE<br>30 | NE<br>24 | NE<br>33 | NE<br>33 | NE<br>28 | NE<br>24 | NNE<br>28 | NNE<br>31 | NNE<br>28 | N<br>22 | NNE<br>22 | NNE<br>20 | NNE<br>24 | NNE<br>20 | NNE<br>9 | N<br>7 | NE<br>46 | 13 | 31 |

Avis/Note C= Calme /Calm M= Manquant /Missing

## Humidité/Humidity

Points de rosée horaires
Hourly dew points

**Montreal - Dorval (AUTO)**

Janvier 2001
January 2001

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -105 | -117 | -129 | -131 | -133 | -133 | -138 | -140 | -138 | -132 | -135 | -139 | -136 | -138 | -133 | -133 | -135 | -137 | -135 | -134 | -133 | -133 | -132 | -132 |
| 2 | -136 | -140 | -141 | -147 | -157 | -159 | -163 | -161 | -160 | -152 | -149 | -149 | -146 | -151 | -151 | -157 | -158 | -159 | -156 | -151 | -150 | -143 | -137 | -134 |
| 3 | -132 | -129 | -125 | -126 | -129 | -124 | -132 | -114 | -103 | -93 | -86 | -77 | -69 | -69 | -67 | -65 | -68 | -69 | -68 | -77 | -82 | -85 | -69 | -61 |
| 4 | -71 | -74 | -65 | -68 | -84 | -87 | -87 | -85 | -82 | -81 | -83 | -87 | -89 | -88 | -89 | -96 | -104 | -105 | -141 | -154 | -159 | -171 | -164 | -173 |
| 5 | -183 | -175 | -175 | -146 | -145 | -152 | -155 | -154 | -146 | -144 | -147 | -138 | -126 | -102 | -105 | -106 | -96 | -93 | -100 | -88 | -94 | -96 | -94 | -94 |
| 6 | -99 | -98 | -94 | -91 | -87 | -87 | -85 | -83 | -81 | -71 | -66 | -70 | -70 | -71 | -69 | -67 | -67 | -64 | -62 | -63 | -61 | -56 | -57 | -55 |
| 7 | -57 | -60 | -63 | -69 | -71 | -75 | -75 | -82 | -83 | -85 | -83 | -86 | -83 | -85 | -88 | -90 | -91 | -88 | -88 | -87 | -84 | -80 | -75 | -76 |
| 8 | -73 | -71 | -72 | -75 | -76 | -76 | -76 | -77 | -78 | -82 | -80 | -84 | -81 | -83 | -85 | -83 | -83 | -84 | -82 | -82 | -80 | -80 | -77 | -74 |
| 9 | -75 | -71 | -76 | -80 | -95 | -112 | -127 | -152 | -161 | -169 | -177 | -179 | -176 | -177 | -180 | -176 | -166 | -155 | -155 | -159 | -164 | -166 | -180 | -186 |
| 10 | -190 | -205 | -211 | -213 | -205 | -211 | -216 | -209 | -212 | -207 | -203 | -210 | -209 | -204 | -189 | -183 | -186 | -186 | -191 | -192 | -192 | -167 | -152 | -164 |
| 11 | -145 | -118 | -101 | -92 | -94 | -117 | -108 | -99 | -93 | -75 | -58 | -46 | -49 | -92 | -95 | -112 | -125 | -135 | -141 | -143 | -150 | -137 | -136 | -138 |
| 12 | -142 | -141 | -144 | -153 | -158 | -168 | -169 | -167 | -171 | -165 | -146 | -143 | -145 | -145 | -148 | -149 | -152 | -150 | -150 | -154 | -147 | -149 | -156 | -166 |
| 13 | -151 | -153 | -153 | -160 | -159 | -151 | -160 | -162 | -147 | -138 | -130 | -124 | -116 | -110 | -108 | -101 | -100 | -91 | -88 | -89 | -97 | -96 | -85 | -82 |
| 14 | -73 | -65 | -50 | -50 | -50 | -40 | -39 | -36 | -32 | -30 | -29 | -38 | -43 | -51 | -56 | -52 | -64 | -97 | -118 | -126 | -133 | -135 | -140 | -147 |
| 15 | -151 | -153 | -156 | -155 | -155 | -157 | -151 | -146 | -147 | -147 | -140 | -128 | -126 | -122 | -120 | -118 | -108 | -101 | -98 | -97 | -97 | -101 | -99 | -98 |
| 16 | -93 | -91 | -84 | -81 | -81 | -82 | -80 | -75 | -65 | -65 | -66 | -63 | -61 | -57 | -54 | -53 | -53 | -54 | -65 | -67 | -69 | -76 | -85 | -95 |
| 17 | -103 | -112 | -127 | -136 | -139 | -121 | -120 | -120 | -119 | -123 | -129 | -129 | -132 | -137 | -145 | -140 | -147 | -156 | -164 | -164 | -169 | -173 | -182 | -180 |
| 18 | -180 | -192 | -206 | -202 | -207 | -229 | -238 | -197 | -182 | -157 | -177 | -140 | -140 | -158 | -145 | -132 | -133 | -127 | -112 | -112 | -136 | -130 | -127 | -122 |
| 19 | -115 | -114 | -114 | -109 | -104 | -101 | -96 | -89 | -76 | -64 | -42 | -38 | -29 | -31 | -31 | -30 | -32 | -31 | -70 | -103 | -117 | -132 | -159 | -166 |
| 20 | -176 | -182 | -195 | -204 | -205 | -212 | -209 | -205 | -204 | -201 | -206 | -197 | -180 | -178 | -196 | -172 | -176 | -188 | -207 | -235 | -209 | -208 | -242 | -214 |
| 21 | -226 | -244 | -249 | -264 | -256 | -241 | -255 | -232 | -240 | -236 | -213 | -213 | -200 | -178 | -152 | -139 | -129 | -129 | -115 | -120 | -117 | -116 | -121 | -124 |
| 22 | -133 | -133 | -142 | -151 | -172 | -174 | -175 | -190 | -168 | -175 | -161 | -159 | -146 | -142 | -136 | -136 | -138 | -140 | -132 | -130 | -129 | -113 | -107 | -98 |
| 23 | -88 | -77 | -66 | -72 | -80 | -85 | -88 | -84 | -85 | -82 | -72 | -69 | -55 | -49 | -50 | -48 | -48 | -45 | -40 | -34 | -28 | -27 | -27 | -24 |
| 24 | -19 | -17 | -14 | -15 | -16 | -17 | -20 | -20 | -21 | -20 | -15 | -13 | -15 | -16 | -24 | -30 | -30 | -35 | -41 | -39 | -43 | -34 | -31 | -16 |
| 25 | -17 | -20 | -32 | -42 | -56 | -62 | -67 | -83 | -103 | -114 | -123 | -129 | -119 | -126 | -137 | -151 | -157 | -160 | -152 | -151 | -153 | -137 | -159 | -168 |
| 26 | -150 | -159 | -143 | -138 | -134 | -118 | -123 | -124 | -123 | -113 | -95 | -84 | -76 | -71 | -59 | -57 | -61 | -64 | -68 | -71 | -71 | -74 | -71 | -67 |
| 27 | -70 | -68 | -69 | -71 | -71 | -71 | -78 | -82 | -87 | -83 | -88 | -80 | -73 | -72 | -74 | -72 | -70 | -67 | -71 | -65 | -69 | -68 | -65 | -53 |
| 28 | -66 | -71 | -103 | -114 | -122 | -131 | -149 | -155 | -164 | -160 | -161 | -156 | -157 | -163 | -167 | -164 | -169 | -203 | -226 | -199 | -202 | -203 | -198 | -198 |
| 29 | -200 | -206 | -216 | -194 | -170 | -189 | -160 | -191 | -166 | -119 | -100 | -99 | -93 | -81 | -79 | -60 | -61 | -68 | -77 | -80 | -83 | -75 | -73 | -79 |
| 30 | -77 | -88 | -92 | -108 | -98 | -120 | -85 | -63 | -51 | -39 | -30 | -54 | -55 | -58 | -57 | -58 | -54 | -49 | -47 | -43 | -39 | -37 | -34 | -34 |
| 31 | -37 | -46 | -60 | -65 | -67 | -72 | -76 | -81 | -85 | -84 | -89 | -92 | -88 | -92 | -93 | -95 | -98 | -103 | -105 | -107 | -107 | -109 | -109 | -108 |

Unités / Units: 0.1 °C

M = Manquant / Missing

Humidités relatives horaires
Hourly relative humidities

Janvier 2001
January 2001

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 72 | 72 | 68 | 73 | 73 | 71 | 74 | 75 | 76 | 81 | 78 | 74 | 73 | 71 | 71 | 71 | 71 | 72 | 74 | 74 | 78 | 79 | 80 | 79 |
| 2 | 80 | 80 | 78 | 80 | 81 | 81 | 83 | 85 | 83 | 85 | 83 | 80 | 78 | 81 | 78 | 74 | 73 | 73 | 73 | 75 | 73 | 76 | 78 | 78 |
| 3 | 77 | 79 | 81 | 81 | 83 | 85 | 84 | 83 | 83 | 87 | 86 | 86 | 83 | 79 | 77 | 76 | 73 | 75 | 76 | 68 | 67 | 66 | 79 | 87 |
| 4 | 78 | 75 | 87 | 87 | 79 | 79 | 79 | 80 | 83 | 86 | 85 | 82 | 77 | 79 | 77 | 74 | 72 | 75 | 62 | 62 | 64 | 71 | 71 | 79 |
| 5 | 82 | 85 | 83 | 87 | 78 | 75 | 75 | 73 | 76 | 76 | 77 | 74 | 74 | 71 | 79 | 81 | 84 | 87 | 86 | 88 | 87 | 87 | 86 | 87 |
| 6 | 87 | 87 | 87 | 87 | 87 | 86 | 87 | 87 | 88 | 89 | 86 | 85 | 85 | 83 | 75 | 80 | 80 | 84 | 84 | 83 | 84 | 87 | 89 | 89 |
| 7 | 89 | 88 | 87 | 85 | 87 | 86 | 87 | 87 | 86 | 84 | 84 | 81 | 76 | 71 | 67 | 70 | 71 | 82 | 79 | 81 | 81 | 79 | 81 | 78 |
| 8 | 81 | 83 | 83 | 84 | 83 | 83 | 83 | 84 | 85 | 84 | 86 | 84 | 86 | 86 | 82 | 81 | 80 | 79 | 81 | 81 | 82 | 82 | 84 | 84 |
| 9 | 86 | 88 | 87 | 87 | 84 | 83 | 81 | 78 | 80 | 78 | 76 | 76 | 75 | 75 | 72 | 72 | 80 | 83 | 83 | 83 | 81 | 80 | 73 | 74 |
| 10 | 76 | 80 | 81 | 80 | 77 | 76 | 78 | 79 | 77 | 75 | 70 | 64 | 60 | 59 | 62 | 62 | 60 | 61 | 60 | 61 | 65 | 73 | 75 | 66 |
| 11 | 73 | 87 | 90 | 91 | 91 | 89 | 89 | 89 | 88 | 89 | 89 | 85 | 85 | 60 | 60 | 54 | 52 | 51 | 56 | 56 | 60 | 59 | 58 | 61 |
| 12 | 62 | 64 | 66 | 58 | 71 | 79 | 79 | 81 | 78 | 81 | 78 | 73 | 69 | 66 | 63 | 61 | 59 | 65 | 69 | 76 | 76 | 82 | 83 | 86 |
| 13 | 87 | 86 | 84 | 81 | 83 | 84 | 88 | 85 | 86 | 85 | 77 | 73 | 77 | 78 | 77 | 77 | 75 | 79 | 79 | 76 | 73 | 72 | 77 | 77 |
| 14 | 78 | 81 | 83 | 83 | 83 | 86 | 85 | 85 | 86 | 85 | 84 | 75 | 72 | 69 | 63 | 66 | 63 | 60 | 54 | 55 | 55 | 56 | 58 | 56 |
| 15 | 58 | 61 | 63 | 65 | 68 | 68 | 70 | 72 | 73 | 73 | 74 | 78 | 80 | 81 | 79 | 80 | 85 | 87 | 86 | 85 | 86 | 85 | 85 | 85 |
| 16 | 88 | 88 | 90 | 90 | 90 | 88 | 87 | 88 | 88 | 88 | 88 | 89 | 87 | 85 | 83 | 82 | 80 | 80 | 73 | 73 | 73 | 72 | 70 | 68 |
| 17 | 70 | 73 | 74 | 79 | 77 | 81 | 83 | 83 | 85 | 84 | 82 | 82 | 79 | 76 | 74 | 71 | 71 | 70 | 71 | 71 | 74 | 76 | 79 | 84 |
| 18 | 84 | 85 | 83 | 83 | 78 | 77 | 75 | 79 | 85 | 86 | 80 | 84 | 77 | 77 | 78 | 77 | 81 | 82 | 83 | 85 | 82 | 82 | 82 | 83 |
| 19 | 83 | 83 | 83 | 84 | 84 | 83 | 82 | 82 | 82 | 85 | 87 | 85 | 89 | 81 | 81 | 83 | 84 | 89 | 73 | 64 | 68 | 70 | 61 | 70 |
| 20 | 67 | 70 | 67 | 67 | 70 | 74 | 76 | 80 | 81 | 81 | 70 | 57 | 76 | 74 | 55 | 66 | 75 | 71 | 68 | 69 | 70 | 75 | 80 | 81 |
| 21 | 73 | 77 | 67 | 72 | 72 | 74 | 72 | 76 | 77 | 79 | 80 | 71 | 67 | 71 | 78 | 79 | 82 | 79 | 87 | 83 | 83 | 83 | 81 | 84 |
| 22 | 84 | 86 | 83 | 74 | 73 | 78 | 85 | 89 | 79 | 69 | 69 | 67 | 71 | 71 | 71 | 72 | 71 | 80 | 84 | 84 | 83 | 85 | 83 | 83 |
| 23 | 87 | 86 | 81 | 80 | 80 | 81 | 83 | 76 | 75 | 72 | 74 | 73 | 72 | 71 | 68 | 69 | 69 | 72 | 75 | 77 | 80 | 82 | 82 | 84 |
| 24 | 88 | 91 | 92 | 93 | 94 | 94 | 95 | 92 | 90 | 88 | 92 | 92 | 88 | 83 | 77 | 75 | 74 | 76 | 79 | 84 | 85 | 83 | 89 | 98 |
| 25 | 99 | 99 | 97 | 93 | 91 | 89 | 89 | 85 | 78 | 73 | 69 | 68 | 72 | 73 | 68 | 63 | 60 | 61 | 69 | 74 | 75 | 76 | 76 | 83 |
| 26 | 84 | 91 | 86 | 82 | 83 | 76 | 77 | 79 | 81 | 85 | 80 | 78 | 74 | 70 | 68 | 70 | 71 | 72 | 73 | 78 | 73 | 83 | 86 | 88 |
| 27 | 85 | 89 | 85 | 86 | 86 | 88 | 84 | 87 | 90 | 91 | 89 | 87 | 86 | 81 | 77 | 74 | 77 | 80 | 81 | 84 | 85 | 85 | 86 | 92 |
| 28 | 88 | 91 | 80 | 81 | 82 | 84 | 83 | 85 | 86 | 82 | 79 | 73 | 68 | 58 | 54 | 54 | 53 | 45 | 34 | 48 | 45 | 52 | 53 | 61 |
| 29 | 67 | 72 | 72 | 72 | 89 | 96 | 91 | 82 | 92 | 89 | 93 | 81 | 76 | 76 | 72 | 76 | 77 | 68 | 67 | 68 | 74 | 78 | 83 | 85 |
| 30 | 90 | 92 | 95 | 94 | 97 | 94 | 95 | 97 | 96 | 91 | 94 | 91 | 88 | 92 | 95 | 94 | 93 | 92 | 93 | 94 | 94 | 95 | 96 | 96 |
| 31 | 93 | 90 | 85 | 86 | 86 | 85 | 84 | 83 | 84 | 88 | 86 | 85 | 89 | 88 | 90 | 91 | 90 | 88 | 88 | 86 | 86 | 83 | 83 | 85 |

Unités / Units: pourcent / percent (%)

M = Manquant / Missing

- Résumé / Summary -

| **Sommaire quotidien de janvier 2001**<br>**Aéroport International de Montréal/Dorval** | | **Daily summary for January 2001**<br>**Montreal/Dorval International Airport** | |
|---|---|---|---|
| Date | | Date | |
| 1 - | Flocons en avant-midi et en soirée. Venteux. | 1 - | Morning and evening flurries. Windy. |
| 2 - | Flocons surtout vers midi. Froid et venteux. | 2 - | Flurries especially around noon. Cold. Windy. |
| 3 - | Faible neige en avant-midi et en soirée. Doux. | 3 - | Morning and evening light snow. Mild. |
| 4 - | Faible neige cessant en après-midi. | 4 - | Light snow ending in the afternoon. |
| 5 - | Neige surtout en après-midi et en soirée. | 5 - | Snow especially in the afternoon and evening. |
| 6 - | Faible neige intermittente. Doux. | 6 - | Light intermittent snow. Mild. |
| 7 - | Faible neige le matin. Soleil en après-midi. Flocons en soirée. Doux. | 7 - | Light morning snow. Sunny in the afternoon. Evening flurries. Mild. |
| 8 - | Neige cessant en après-midi. Flocons en soirée. Doux. | 8 - | Snow ending in the afternoon. Flurries in the evening . Mild. |
| 9 - | Neige surtout en après-midi. | 9 - | Snow especially in the afternoon. |
| 10 - | Ensoleillé. Flocons en fin de soirée. Froid. | 10 - | Sunny. Evening flurries. Cold. |
| 11 - | Faible neige et bruine verglaçante durant la nuit. Faible neige en avant-midi. Soleil en après-midi. Doux. | 11 - | Light snow and freezing drizzle overnight. Light snow in the morning. Sunny in the afternoon. Mild. |
| 12 - | Ensoleillé. | 12 - | Sunny. |
| 13 - | Ennuagement le matin. | 13 - | Clouding over in the morning. |
| 14 - | Nuageux avec éclaircies. Très doux. | 14 - | Cloudy with breaks. Very Mild. |
| 15 - | Faible neige débutant en avant-midi mêlée de bruine verglaçante en après-midi et en fin de soirée. Venteux. | 15 - | Light snow beginning in the morning mixed with freezing drizzle in the afternoon and by late evening. Windy. |
| 16 - | Faible neige, mêlée de bruine verglaçante la nuit, devenant de la neige intermittente le matin cessant après midi. Flocons en soirée. Doux. | 16 - | Light snow, mixed with freezing drizzle at night, becoming intermittent snow in the morning ending after noon. Evening flurries. Mild. |
| 17 - | Neige cessant vers midi. | 17 - | Snow ending around noon. |
| 18 - | Soleil le matin. Flocons en après-midi. Froid. | 18 - | Sunny in the morning. Afternoon flurries. Cold. |
| 19 - | Bruine verglaçante mêlée de faible neige en matinée. Doux. | 19 - | Freezing drizzle mixed with light snow during the morning. Mild. |
| 20 - | Ensoleillé. Froid. | 20 - | Sunny. Cold. |
| 21 - | Faible neige intermittente en après-midi et en soirée. Froid. | 21 - | Light intermittent snow in the afternoon and in the evening. Cold. |
| 22 - | Ensoleillé. Moins froid. | 22 - | Sunny. Warmer. |
| 23 - | Nuageux. Flocons en fin de soirée. Doux. | 23 - | Cloudy. Late evening flurries. Mild. |
| 24 - | Neige cessant avant midi. Et recommençant en fin de soirée. Très doux. | 24 - | Snow ending before noon. And starting over by late evening. Very mild. |
| 25 - | Faible neige cessant en avant-midi. | 25 - | Light snow ending during the morning. |
| 26 - | Plutôt ensoleillé. Doux. | 26 - | Mainly sunny. Mild. |
| 27 - | Faibles averses de neige vers midi et en soirée. Doux. | 27 - | Light snowflurries around noon and during the evening. Mild. |
| 28 - | Flocons durant la nuit. Ensoleillé. | 28 - | Flurries overnight. Sunny. |
| 29 - | Plutôt nuageux. Doux. | 29 - | Mainly cloudy. Mild. |
| 30 - | Neige débutant en avant-midi. Doux et venteux. | 30 - | Snow beginning in the morning. Mild. Windy. |
| 31- | Neige surtout en après midi. Doux et venteux. | 31 - | Snow especially in the afternoon. Mild. Windy. |

# APPENDIX F

## EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS

BM3833

# EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS

Winter 2000/2001

Prepared for

**Transportation Development Centre**
**Transport Canada**

Prepared by: John D'Avirro

APS AVIATION INC.

November 09, 2000
Version 1.0

# Experimental Procedure for the Collection of Fog Rates of Deposition in Natural Conditions

Winter 2000/2001

## 1. OBJECTIVE

The objective of this study is to determine the range of deposition rates that occur naturally in fog.

## 2. PLAN

Collect fog deposition rates on several occasions in periods of natural fog or freezing fog.

## 3. PROCEDURE

A precipitation collection pan will be used to measure fog deposition rates in natural conditions. Prior to the start of the test, a collection pan will be coated with Ultra+ Type IV fluid (see flat plate test procedure) and weighed. The pan weight (in grams) and the test start time (hh:mm:ss) will then be recorded on a meteo/plate pan data form. In order to simulate the taxi of an aircraft in fog conditions, the collection pan will be mounted on a stand positioned on the hood of a car. In preliminary trials, the mounted pan will be inclined forward at 10°. Prior to the start of the test, zero the car odometer. The vehicle with the mounted plate pan should then be accelerated to a speed not exceeding 30 km/h for a period of 10 minutes to 30 minutes in order to collect precipitation. Following the test, the distance traveled during the test will be recorded along with the test end time in order to calculate the average velocity during the test. Finally, the precipitation pan will be re-weighed in order to evaluate the fog catch.

An estimate of visibility will be made based on markers on the road (such as lamp poles).

Tests shall be repeated if conditions are still appropriate.

## 4. PERSONNEL

One research assistant is required for these tests.

## 5. DATA FORMS

A Meteo / Plate Pan data form (see Table F-1) is required for these tests.

## 6. EQUIPMENT

- Weigh scale
- Precipitation plate pan
- Test plate mount for vehicle
- Inclinometer
- Type IV Ultra+ fluid

# TABLE F-1

Winter 2000/2001

LOCATION: DATE: RUN # :

## PLATE PAN WEIGHT MEASUREMENTS

| PAN # | t TIME BEFORE (hr:min:ss) | t TIME AFTER (hr:min) | w WEIGHT BEFORE (grams) | w WEIGHT AFTER (grams) | COMPUTE RATE (Δ w*4.7/ Δt) (g/dm²/h) |
|---|---|---|---|---|---|
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## COLLECTION PERIOD INFORMATION

| TIME BEFORE (hr:min:ss) | TIME AFTER (hr:min:ss) | TOTAL DISTANCE TRAVELED |
|---|---|---|
| | | |
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| | | |
| | | |

TEMPERATURE AT START OF TEST ______ °C

ESTIMATED VISIBILITY ______ Miles

DAY OR NIGHT ______

COMMENTS : ______

WRITTEN & PERFORMED BY : ______ PRINT ______ SIGN

# APPENDIX G

# WINTER OPERATIONS SURVEY

Transports
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Transport
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*Votre référence* *Your file*

*Notre référence* *Our file*

June 22, 2001

**SUBJECT: Winter Operations Survey**

Dear Sir or Madam:

Transport Canada is attempting to collect data on actual deicing operations at several worldwide stations.

We are seeking this information in support of a review of the Holdover time table temperature and weather condition breakdowns such that we can ensure that our R&D emphasis is aimed at conditions where an important number of operations occur worldwide. It will also assist us in identifying where improvements can be made to the format. Your inputs and data will ensure that your operational conditions are included in the review process. We shall feed back to you our findings from this survey.

I have attached two tables for this purpose: Table 1 for Type I operations and Table 2 for Type II/IV operations. As examples, I also show estimates from information we have for Dorval in Tables 3 and 4.

Recognizing that you may not have data in this exact format, there are several ways you can provide data. You can provide numbers of deicing operations or percentages and you may need to change temperature breakdowns. If you cannot separate out Type I operations, please provide the information for all fluids on Table 2 and check the appropriate box.

The following are our guidelines for completing the tables:

1. First identify ONE deicing station for which you have data and provide information only for this station. If possible, it should be your busiest winter station in your country. If you cannot separate out one station provide the names of the stations included.
2. Establish your level of operations by stating the number of deicing operations performed in an average winter at the station you have identified.

3. Assess how many or what proportion of your operations are for frost and how many are for snow at the bottom of the table.
4. Assess how many or what proportion of your operations are for freezing rain, freezing drizzle or freezing fog.
5. Assess how many or what proportion of your operations treat for rain on a cold soaked wing.
6. State (or estimate) how many of the operations are in each temperature range in the table and do this for each weather class if possible in the body of the table.
7. Identify or estimate how operations are distributed by temperature on the right of the table.

When you make estimates, please identify that the figure is an estimate with the letter "E" alongside the value. If all entries are estimates, please check the box labelled "Type I included".

For your convenience the tables were saved as Microsoft Excel Workbook (recommended format), Quattro Pro and Word Perfect (both Novell Perfect Office format).

If you need assistance in processing your data into a format for the forms provided, please feel free to call John D'Avirro of APS at 514 878 4388.

Please complete the Tables as best as you can and return them to my attention by July 20, 2001.

Yours Sincerely,

Barry Myers

## TABLE 1 (FOR TYPE I FLUID)
## DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION(S):

**Total # of Deicing Operations:**

**All values are estimates:** ☐

| OAT | | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| °C | °F | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | | | | | | | | |
| 0 to -10 | 32 to 14 | | | | | | | | |
| below -10 | below 14 | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Total** | | | | | | |

**of Operations**

## TABLE 2 (FOR TYPE II / IV FLUID)
## DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

**Total # of Deicing Operations:** ☐ **Type I Included** ☐ **All values are estimates:** ☐

| OAT | | Type IV Fluid Concentration | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | 100/0 | | | | | | | | |
| | | 75/25 | | | | | | | | |
| | | 50/50 | | | | | | | | |
| 0 to -3 | 32 to 27 | 100/0 | | | | | | | | |
| | | 75/25 | | | | | | | | |
| | | 50/50 | | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | | | | | | | | |
| | | 75/25 | | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | | | | | | | | |
| below -25 | below -13 | 100/0 | | | | | | | | |
| | | **Total** | | | | | | | | **of Operations** |

## TABLE 3 (FOR TYPE I FLUID)
## DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

*MONTREAL DORVAL - YUL*

**Total # of Deicing Operations:** *3000*

**All values are estimates:** ☒

| OAT | | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| °C | °F | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | 2.0% | 0.0% | 4.9% | 0.2% | 0.5% | 1.0% | | 8.6% |
| 0 to -10 | 32 to 14 | 9.0% | 0.5% | 49.0% | 0.8% | 1.5% | | | 60.8% |
| below -10 | below 14 | 14.0% | 0.5% | 16.1% | | | | | 30.6% |

| Total | 25.0% | 1.0% | 70.0% | 1.0% | 2.0% | 1.0% |
|---|---|---|---|---|---|---|

**100%** **of Operations**

## TABLE 4 (FOR TYPE II / IV FLUID)
## DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

*MONTREAL DORVAL - YUL*

**Total # of Deicing Operations:** *2000* **Type I Included** ☐ **All values are estimates:** ☒

| OAT | | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Weather Conditions | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| °C | °F | | FROST | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING | OTHER | |
| above 0° | above 32° | 100/0<br>75/25<br>50/50 | 2.0% | 0.0% | 4.9% | 0.2% | 0.5% | 1.0% | | 8.6% |
| 0 to -3 | 32 to 27 | 100/0<br>75/25<br>50/50 | 3.0% | 0.5% | 17.0% | 0.5% | 1.0% | | | 22.0% |
| below -3 to -14 | below 27 to 7 | 100/0<br>75/25 | 10.0% | 0.3% | 42.0% | 0.3% | 0.5% | | | 53.1% |
| below -14 to -25 | below 7 to -13 | 100/0 | 10.0% | 0.3% | 6.1% | | | | | 16.4% |
| below -25 | below -13 | 100/0 | 0.0% | 0.0% | 0.0% | | | | | 0.0% |
| | | **Total** | 25.0% | 1.0% | 70.0% | 1.0% | 2.0% | 1.0% | 100% | **of Operations** |